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TABLE OF CONTENTS

CASTLE LAKE INVESTIGATION—SECOND PHASE: EASTERN BROOK TROUT[1]

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INTRODUCTION

The first phase of the investigation of Castle Lake in Siskiyou County, California, covered the period 1938 to 1946, inclusive (Wales, 1946). During that time four species of trout and two species of minnows were present in the lake. On October 9, 1946, the lake was treated with rotenone and all fish were killed. The water remained toxic to trout until July, 1947.

The second phase of the investigation, covering the period 1947 to 1954, inclusive, is concerned with eastern brook trout (*Salvelinus fontinalis*). The primary objective was to compare the yield of a pure brook trout fishery with that of a fishery in which rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), lake trout (*Salvelinus namaycush*) and brook trout occurred together. Information about growth rates, longevity, trout production, and comparative costs of different planting methods was also obtained.

The writers wish to thank the seasonal aids who carried out the creel censuses and to acknowledge the help of the late Harry P. Chandler, who supervised the field work.

DESCRIPTION OF CASTLE LAKE

Castle Lake is located in the north-central portion of California. It lies at an altitude of 5,200 feet, its surface area is 48 acres, and its maximum depth is 120 feet. It is of fairly typical glacial cirque formation, with abrupt cliffs at the south end, and peaks on either side. The north end is a low moraine, through which the outlet stream has cut. The northern one-third of the lake is shallow, 12 to 15 feet deep, while the remainder is a deep bowl. The total water volume is approximately 1,800 acre-feet. The lake basin is covered by a deep blanket of snow for nearly six months of each year. Melting snow and the several springs on the lake bottom comprise the water source. The surrounding vegetation is composed of a relatively few conifers, considerable brush, and a thin covering of annual plants. The soil is relatively poor and its contribution to the fertility of the lake water is low. In consequence, the lake has few aquatic plants. The bottom is almost completely covered by silt. Bottom food organisms are moderately abundant in the aquatic plant beds, but scarce elsewhere. The water itself is relatively clear; the

[1] Submitted for publication October, 1955. This work (1953-54) was performed as part of Dingell-Johnson Project California F-8-R, "Trout Management Study", supported by Federal Aid to Fish Restoration funds.

Secchi disk visibility ranges from 40-55 feet. Zooplankton is moderately abundant, but phytoplankton is scarce. Temperatures never exceed 75 degrees F. At a depth of 100 feet the temperature drops to 40 degrees F. in the winter and early spring. A thermocline begins to develop at about 20 feet in June and becomes accentuated by September, when it descends to about 35 feet. The oxygen regime is quite variable from month to month and from year to year. Oxygen tensions as low as 1.0 p.p.m. have been recorded at a depth of 100 feet in September.

It cannot be presumed that the results of investigations of any one lake will be identical with results obtained from like studies of any other lake. However, cursory observations on many other lakes during a 20-year period indicate that in general the trout biology of most California lakes within the altitude range of 5,000 to 8,000 feet is similar to that of Castle Lake. We believe, therefore, that the results of our studies of this lake may be applied in a general way to many other waters.

PROGRAM AND METHODS

Table 1 presents the planting record for the second phase of the investigation. It will be noted that brook trout were stocked in 1947 and 1948 only, whereas this report covers the period 1947-54. No fish at all were planted in 1949-51, inclusive, because it was evident in 1948 that the lake was already overpopulated in relation to the food supply. By 1952 it was evident that enough data on brook trout survival had been or eventually would be accumulated. Therefore, in that year rainbow were planted. They will be planted each year until the end of the third or rainbow trout phase of the investigation.

TABLE 1

Planting Record for Brook Trout

Date	Fish	Size	Fin removed
July 3, 1947	20,000 eastern brook	13.3 per lb.	Not marked
Sept. 19, 1947	20,000 eastern brook	5.0 per oz.	RV
Aug. 12, 1948	10,000 eastern brook	12.5 per oz.	Ad
Aug. 12, 1948	10,000 eastern brook	12.5 per oz.	Ad-LV

Since Castle Lake is a favorite recreation spot, it was desirable to provide some angling as soon as the water had lost its toxicity. Therefore, the largest brook trout available were used for the initial stocking on July 3, 1947. Although most of these yearlings would ordinarily be classified as "subcatchables," the heavy fishing intensity resulted in large catches from the time of liberation.

The 20,000 fingerling brooks released on September 19, 1947, were planted to yield data on the survival of such fish to the angler and to compare this survival with that of the yearlings.

The 20,000 fingerling brooks released on August 12, 1948, were intended to provide more information on the return of fingerlings to the angler and on the relative survival of fish with different fins removed.

All of the brook trout were planted by conventional tank trucks, without special precautions or use of drugs. No information is available

regarding the strain or strains of brook trout used. All were from eggs purchased by the Department of Fish and Game from out-of-state commercial sources. They are presumed to have been wild or semiwild, unselected fish.

In order to obtain information on the return of planted fish to the anglers, a complete creel census was conducted each year except 1954, when the census taker was given two days off each week and no relief man provided. In this system two weekdays were not checked each week. For example, Monday and Tuesday were not checked one week, the following week Wednesday and Thursday were not checked, and the following week Friday and the next Monday were missed.

The catch data for weekdays missed were estimated by averaging the corresponding day of the week previous and of the week following.

All Saturdays, Sunday, and holidays were checked. Tests with complete creel census data at Castle Lake had previously shown that this method yields seasonal totals reasonably close to the actual (Best and Boles, 1956).

The census taker resides at a cabin located on the shore of the lake, where the road ends and all cars are parked. The attendant contacts almost all anglers at the end of their fishing day. He measures all fish and records the data on a special form, together with information about the angler, his fishing method, and time expended. Although a few persons are missed in such a survey, the number is not great enough to affect the results significantly.

DISCUSSION

A summary of the angling data for the period 1947-1954, inclusive, is presented in Table 2. In order to understand these data, some knowledge of the planting program is essential.

A few "catchable" rainbow were inadvertently planted with the 20,000 brooks stocked on July 3, 1947. These were probably all removed by the end of the 1948 fishing season.

The heavy plants of yearling brooks in 1947 resulted in an unusually high return that year (Table 3). In 1948 the anglers caught more of this plant and also some of the 1947 plant of fingerling brooks. Similarly, in 1949 and 1950 the catch remained high because of the fingerlings planted in 1947 and 1948, plus some of the yearlings planted in 1947. However, by 1951 the catch dropped off markedly because the hatchery plants of brooks were dwindling, and the wild or naturally spawned brooks were not yet abundant.

In 1952 both catchable-sized and fingerling rainbow were planted. The catchables, plus the considerable number of wild brooks, caused a marked improvement in the fishing that year.

The next year the fishing dropped off somewhat because of the reduction in the stock of rainbow catchables planted the year before and because the contribution of the rainbow fingerlings was not great.

In 1954 the decline in the rainbow catch had gone much further. During 1954, 84 percent of the entire catch was composed of brook trout, despite the fact that none had been planted since the initial stocking in 1947 and 1948. Nearly all of the brooks taken in 1954 were wild fish.

TABLE 2

Summary of Angling Data, 1947-1954, Inclusive

	1947	1948	1949	1950	1951	1952	1953	1954
Fishing season, days	121	163	171	171	187	167	155	171
Number angler days	894	1,213	1,067	1,358	854	1,087	1,429	1,079
Total catch	5,810	5,199	4,928	5,255	2,354	4,506	3,988	2,957
Average catch per day	6.5	4.3	4.6	3.9	2.8	4.1	2.8	2.7
Average hours fished	3.1	3.1	2.6	2.8	3.0	3.3	3.4	3.2
Average catch per hour	2.1	1.4	1.8	1.4	0.9	1.2	0.8	0.9
Rainbow trout caught	45 (1%)	9 (0.2%)	0	0	1	2,326 (52%)	2,160 (54%)	482 (16%)
Brook trout caught	5,765 (99%)	5,190 (99.8%)	4,928	5,255	2,353	2,180 (48%)	1,828 (46%)	2,475 (84%)
Total catch	5,810	5,199	4,928	5,255	2,354	4,506	3,988	2,957

Only 16 percent of the 1954 season's catch consisted of rainbow. There had been no natural reproduction of this species, the 1952 plant of catchables was nearly exhausted, and the contribution of the fingerling plants was small.

The outstanding point here is that the catch of wild brooks increased each year after 1951, when they first entered the catch. Thus, we see that an initial stocking of the lake with brooks may be expected to develop a good, self-sustaining population, even though rainbow are introduced in considerable numbers.

Under heavy fishing pressure, the quality of the angling, if dependent upon wild brook trout alone, would probably not be satisfactory to many fishermen. This would not be the case in "backcountry" lakes, where angling is very much lighter than in Castle Lake. Also, if more spawning area were available, the natural crop of brooks might reach a satisfactory level.

We believe that satisfactory fishing could be maintained by natural reproduction in Castle Lake if either the spawning facilities for brook trout were somewhat greater or the angling intensity were somewhat less. At present, however, in Castle Lake an annual crop of 1,500 wild brooks is insufficient to provide satisfactory fishing for the number of anglers visiting the lake.

Survival to the Creel. In Table 3 each group of planted hatchery brooks is traced in the catches from the year in which they were first taken until they disappeared. Also, the trend in the catch of wild, naturally spawned brooks is shown.

TABLE 3

Annual Catches of Each Group of Brook Trout

Year caught	1947 yearlings, no mark	1947 fingerlings, RV mark	1948 fingerlings, Ad & Ad-LV marks	Wild brooks, no mark
1947	5,765	--	--	--
1948	3,414	1,773	3	--
1949	362	2,415	1,557	--
1950	*128	1,480	3,562	--
1951	--	673	1,526	475
1952	--	371	465	1,344
1953	--	140	116	1,572
1954	--	71	48	2,356
Totals	9,669	6,923	7,277	5,747
Number stocked	20,000	20,000	20,000	--
Percentage caught	48.3	34.6	36.4	--

* Recaptures of this group in subsequent years were obscured by wild fish.

The plant of 20,000 yearling brooks (13.3 per pound) made on July 3, 1947, contributed heavily in the same and in the following season. In their third and fourth years in the lake they made small contributions to the total crop. The total catch of this group was 9,669 or 48.3 percent. This is a relatively low yield for yearlings in comparison with

many waters, especially heavily fished streams and small, heavily fished lakes.

In 1943 a plant of brooks, 10 per pound, returned only 40 percent to the creel in Castle Lake (Wales, 1946). However, these plants are not directly comparable, since in 1943 the fish were larger, and many large, predatory trout were present. In 1947 there were no predatory fish in the lake, so it is not surprising that the fish planted then yielded a higher return than those stocked in 1943.

It is of some importance to fisheries managers that the return of yearling brooks planted in 1943 and 1947 was 40 and 48.3 percent, respectively. A plant of catchable rainbow (7.8 per pound) made in 1952 yielded 80 percent to the angler. However, the plants of brook trout contributed to the catch not only directly but also indirectly through their offspring, while the rainbow did not spawn successfully.

The lot of 20,000 fingerling brooks planted on September 19, 1947, made a good contribution to the catch starting the following year. However, they were then still small and a greater number were taken in 1949, when they had grown to a larger size. They continued to make a good contribution in 1950, but their numbers diminished steadily thereafter until in 1954 only 71 were caught. The total return was 6,923, or 34.6 percent.

The catch pattern of the 20,000 fingerlings planted in 1948 was much the same, with 36.4 percent eventually taken by anglers.

These returns are unusually high for fingerling plants of eastern brook trout.

Prior to the treatment of Castle Lake with rotenone in 1946, the return to the angler of brook fingerling plants ranged from 0.4 to 3.2 percent, with an average of 1.9 percent (Wales, 1946).

It is assumed that the large number of predatory lake, brown, and rainbow trout in the lake prior to 1946 caused the low return of fingerlings, whereas the absence of these fish after chemical treatment permitted a much higher survival.

For the same reason the life span of brook trout in Castle Lake prior to 1946 was three years; none was found to reach four years. In marked contrast, a considerable number of marked hatchery brooks have now attained seven years and a few may be expected to live to an even greater age.

We may conclude from these studies that predation by other fish upon brook fingerlings is an extremely important mortality factor under conditions of this general nature. The increase in survival to the angler from less than 2 percent to approximately 35 percent is assumed to be due entirely to the removal of predatory fish. Also, it was found that prior to the removal of the fish predators there was a slightly greater survival to the angler from the larger brook fingerlings, while after these predators had been removed fingerlings weighing 5.0 fish per ounce had a lower survival than those weighing 12.5 per ounce.

The fingerlings planted in 1948 were divided into two equal lots of 10,000 each, one of which was marked by removal of the adipose fin and the other by removal of the adipose and left ventral fins. We believed that the survival of the latter group would be lower if the absence of a ventral fin was harmful. Table 4 clearly shows that the removal of the adipose and left ventral is not more harmful than the re-

TABLE 4

Catch by Year of Two Groups of Brook Trout Fingerlings

Year	Adipose removed	Adipose and left ventral removed
1948	1	2
1949	714	843
1950	1,666	1,896
1951	735	791
1952	222	243
1953	49	67
1954	23	25
Totals	3,410	3,867

moval of the adipose alone (in fact, the survival to the angler was actually better). Of the 10,000 adipose-marked fingerlings, 34.1 percent were eventually caught, while 38.7 percent of those marked adipose and left ventral were taken. Figure 1 shows the growth rates of the two groups to be practically identical.

In the 1946 report Wales computed costs of brook trout caught by the anglers in Castle Lake. At that time it was assumed that the fingerling brooks cost approximately 1 cent each at planting time and that the yearlings cost approximately 5 cents each. More recent cost figures indicate that the fingerlings still cost 1 cent each, but the yearlings cost 15 cents. Using the survival data from the 1946 report and the corrected cost figures, we find that prior to chemical treatment each brook trout planted as a fingerling cost $0.525 "in the creel", whereas after the lake was treated the cost was down to $0.03. There was relatively little difference in the cost to the angler of brook trout planted as yearlings. Before treatment it was $0.375 each and afer treatment it was $0.35.

Quality of Angling. The quality of the angling for brook trout in Castle Lake during the period 1947-1954, inclusive, is rated by the authors as follows: the "catch per hour" and the "food quality" were high; the "size of fish" was medium; and the "gameness" was low.

The catch per hour of fishing effort while brooks alone were present declined from 2.1 in 1947 to 0.9 in 1951. It is common knowledge that brook trout in California lakes are "free risers" and when abundant can be caught easily on a fly by anyone with a moderate amount of skill. They can be caught from the shore almost as easily as from a boat except during the midsummer lull, when trolling with spinner and bait is usually the only successful method.

Unfortunately, in California lakes brook trout rarely attain desirable size. Although the largest brook ever measured at Castle Lake was 18.4 inches, fork length, fish a foot long are rare. The average fork length of all brooks caught during the years 1947 through 1954 was 7.0 inches, which is fairly typical for northern California lakes. Isolated lakes commonly contain more large fish, probably because the lesser amount of angling permits more fish to reach an older age.

It is also probable that those foods which promote rapid growth and which are necessary for brooks to attain a large size are scarce in Castle Lake. In this lake rainbow are known to attain a weight of six

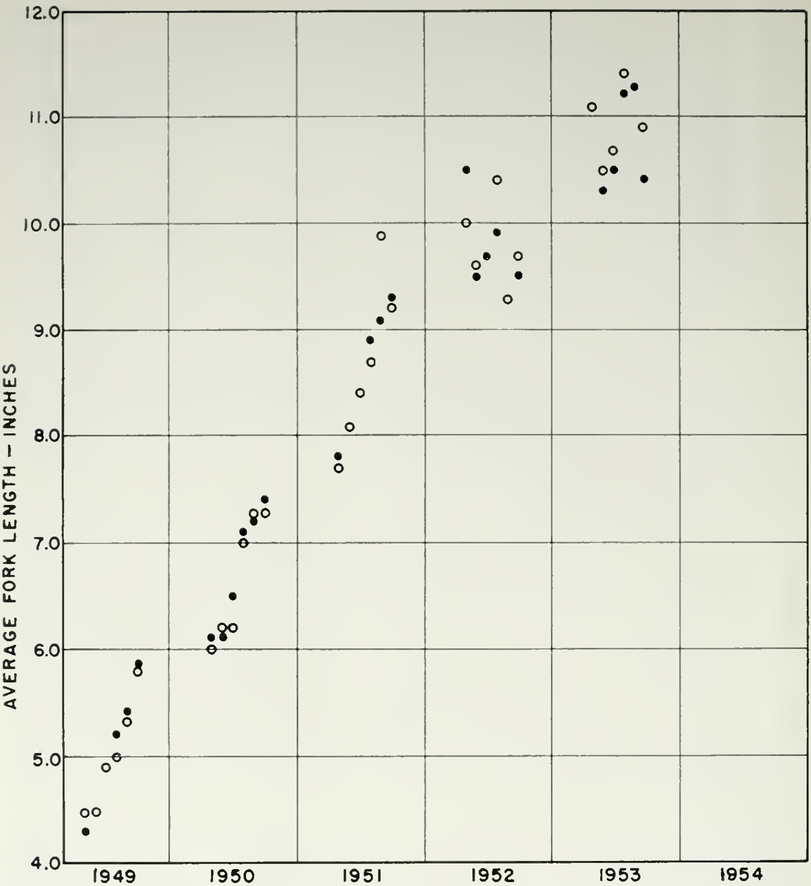

FIGURE 1. Growth of brook trout planted as fingerlings in Castle Lake, Siskiyou County. The open circles represent fingerlings marked by removal of the adipose fin and the solid circles represent fingerlings marked by removal of the adipase and left ventral fins. Each circle indicates the average fork length of all of the fish of the particular class caught during a month.

pounds, brown trout nine pounds, and lake trout 18 pounds, while the largest brook trout recorded weighed 2 pounds 14 ounces.

The gameness of brook trout in lakes of this type is relatively low. This is partly a species characteristic, but perhaps even more a result of their small size.

The food quality of brook trout in the mountain lakes of California is commonly rated above that of rainbow and browns. In waters with good populations of red copepods the brook trout commonly have pink meat and such fish are excellent eating.

In general, the brook trout in Castle Lake appears to be well regarded by the angling public. However, it is not highly regarded by the expert fly fisherman, who prefers the brown or rainbow, especially the steelhead-rainbow. Nor is the brook highly regarded by those who want large trout or by those who prefer boat trolling. Brooks can be

taken by boat trolling in Castle Lake, but their average size is too small to provide good sport by that method.

Table 5 shows the small number of limit catches (15 fish) which have been taken each year since the lake was treated with rotenone. During the period 1941-45, inclusive, while four species of trout were present in Castle Lake, the percentage of angler-days yielding no fish was 42 percent. While only brook trout were in the lake (1947-51, inclusive), the percentage of zero catches was 36 percent. In 1947, when the lake was admittedly overstocked with yearling brooks, the percentage of angler-days yielding limit catches was relatively high (18 percent) and the percentage of anglers catching no fish was somewhat below average (23 percent).

TABLE 5

Number and Percentage of Limit and Zero Catches in Castle Lake

	Limit catches		Zero catches	
	Number	Percentage	Number	Percentage
1947	162	18	204	23
1948	93	8	343	28
1949	126	12	400	37
1950	144	9	559	48
1951	58	7	417	49
1952	79	7	359	33
1953	41	2.9	554	39
1954	61	6	524	48

From Table 6 it may be seen that before 1947, when four species of trout were present in the lake, 50 percent of the annual catch was made by relatively few anglers. After the lake had been treated and replanted with brook trout, the fishing success was spread out among a larger number of anglers.

TABLE 6

Distribution of Fish Among the Fishermen

Year	Number of anglers catching over 50 percent of total catch	Percentage of total anglers
1943	15	7
1944	10	6
1945	13	9
1946	20	5
1947	70	20
1948	77	18
1949	67	9
1950	55	12
1951	34	10
1952	83	13
1953	82	7
1954	39	7

Table 7 shows some interesting changes in the distribution of the catch according to lure used. It will be noted that prior to 1947 spinners were used very effectively. After the lake was restocked with brook

trout in that year, relatively few fish were caught on spinners and the percentage taken on flies increased greatly. However, by 1950 the total number of fish in the lake had decreased and the trend was toward spinners and away from flies. As fishing became poorer in 1953 and 1954, it became necessary for the average angler to use either bait or spinners to take fish.

TABLE 7

Distribution of Catch According to Lure Used (Percentage)

	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Spinner	45	55	51	34	4	11	11	21	31	28	32	35
Bait	39	19	29	48	43	48	32	57	48	58	60	60
Fly	16	26	20	18	53	41	57	27	21	14	8	5

Growth Rate. The data graphed in Figure 2 permit a comparison of the growth rates of brook trout planted as yearlings and those planted as fingerlings. We believe that a small number of this group lived longer than Figure 2 indicates, but in 1950 the wild, naturally spawned offspring of this original hatchery plant entered the catch and obscured the data, since they, like their parents, were unmarked. Occasionally an unmarked fish was caught which had the characteristics of a relatively old fish and these we were reasonably sure were of the 1947 plant of yearlings.

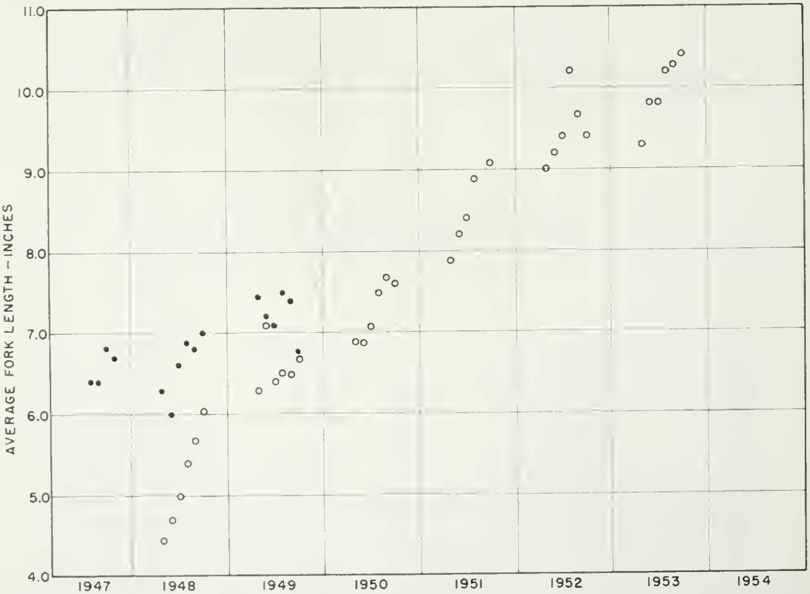

FIGURE 2. Comparison of the growth of brook trout planted as fingerlings and yearlings in Castle Lake, Siskiyou County, in 1947. The open circles represent the fingerlings (5.0 per ounce) and the solid circles represent the yearlings (13.3 per pound). Each circle indicates the average fork length of all of the fish of the particular class caught during a month.

One point should be made clear: the food supply of the lake was reduced by the rotenone treatment of 1946. This was demonstrated by routine plankton sampling, which showed that copepods in particular had been hit hard by the treatment, with one species virtually eliminated. Also, the plant of 20,000 fish, all of the same age and approximately the same size, probably brought about a shortage of the preferred food items. Probably half the allotment, or 10,000 yearling brooks, would have been more suitable for this barren 48-acre lake.

The data in Figure 2 indicate that fingerling brooks do not suffer an appreciable retardation of growth after planting, whereas yearling brook do.

TABLE 8

Average Fork Length in Inches of the 1947 Plant of Brook Yearlings in Castle Lake *

	1947	1948	1949
May	----------	6.3 (100)	7.45 (83)
June	----------	6.0 (100)	7.2 (111)
July	6.4 (1,322)	6.6 (100)	7.1 (97)
August	6.4 (1,252)	6.9 (100)	7.5 (22)
September	6.8 (725)	6.8 (75)	7.4 (23)
October	6.7 (989)	7.0 (98)	6.75 (26)

* The number of fish used for each length average are given in parentheses.

Further comment on the growth rate of the fingerling plants is justified, since roughly half of all the mountain lakes of California are stocked with brook trout fingerlings at least occasionally. Fingerlings weighing about 12 per ounce, when liberated in a lake such as Castle Lake during midsummer, do not enter the catch during that fishing season. However, some are caught by the following May, when they are one year plus in age. At this time they are about 4.5 inches in fork length. During that season they will grow more than an inch and in May of the following year, when they are two plus years in age, their fork length is about six inches. During this season the growth rate, as measured by length, continues at about the same rate and they are over seven inches long by fall. Similarly, in the following year, when they are three plus years in age, they add approximately an inch and a half and by the end of that fishing season they are over nine inches long. The following year, when they are four plus years in age, the growth rate appears to diminish. (If they are not yet nine inches long by their fourth year, this decline in growth rate will occur in the fifth year.)

From a comparison of either Table 10 or 11 with Table 9 it will be noted that when the fish have reached the length of nine inches their growth declines, whether this be in the fourth or the fifth year of their life. Apparently this is due to some factor such as the lack of suitable foods for brook trout of this size or to selective fishing and is probably not due to an inherent growth peculiarly. Therefore, during the fishing season in which they are nine inches long, the growth is negligible. However, during the following year the growth rate increases and the fish attain a fork length of over 10 inches.

TABLE 9

Average Fork Length in Inches of 1947 Plant of Brook Fingerlings Marked RV *

	1948		1949		1950		1951		1952		1953	
May	1.45	(2)	6.3	(705)	6.9	(495)	7.9	(202)	9.0	(4)	9.3	(6)
June	4.7	(100)	7.1	(696)	6.9	(498)	8.2	(171)	9.2	(169)	9.8	(34)
July	5.0	(100)	6.4	(479)	7.1	(234)	8.4	(21)	9.4	(96)	9.8	(64)
August	5.4	(100)	6.5	(147)	7.5	(87)	8.9	(16)	10.2	(4)	10.2	(17)
September	5.7	(83)	6.5	(127)	7.7	(39)			9.7	(2)	10.3	(6)
October	6.05	(100)	6.7	(259)	7.6	(96)	9.1	(118)	9.4	(99)	10.4	(17)

* The number of fish used for each length average are given in parentheses.

TABLE 10

Average Fork Length in Inches of 1948 Plant of Brook Fingerlings Marked Ad *

	1949		1950		1951		1952		1953	
May	4.5	(9)	6.0	(557)	7.7	(284)	10.0	(2)	11.1	(1)
June	4.5	(98)	6.2	(621)	8.1	(219)	9.6	(119)	10.5	(13)
July	4.9	(174)	6.2	(241)	8.4	(32)	9.7	(66)	10.7	(30)
August	5.0	(107)	7.0	(98)	8.7	(14)	10.4	(3)	11.4	(4)
September	5.35	(110)	7.3	(31)	9.9	(4)	9.3	(2)		
October	5.8	(216)	7.3	(89)	9.2	(64)	9.7	(22)	10.9	(1)

* The number of fish used for each length average are given in parentheses.

TABLE 11

Average Fork Length in Inches of 1948 Plant of Brook Fingerlings Marked Ad-LV *

	1949		1950		1951		1952		1953	
May	4.3	(12)	6.1	(637)	7.8	(319)	10.5	(2)		
June	4.5	(122)	6.1	(723)	8.1	(225)	9.5	(147)	10.3	(15)
July	4.9	(178)	6.5	(297)	8.4	(23)	9.7	(56)	10.5	(39)
August	5.2	(145)	7.1	(98)	8.9	(12)	9.9	(5)	11.2	(1)
September	5.4	(151)	7.2	(34)	9.1	(9)			11.5	(3)
October	5.85	(235)	7.4	(75)	9.3	(49)	9.5	(29)	10.4	(8)

* The number of fish used for each length average are given in parentheses.

As we see from Tables 10 and 11, these plants of fish attained approximately the same length by their fourth year that the previous year's plant of fingerlings attained in their fifth year. This is probably due to a lack of food soon after the lake was chemically treated. As we have pointed out, the treatment itself reduced the plankton and the lake was probably too heavily stocked in 1947. We believe that in most lakes similar to Castle Lake, which have not been recently treated with rotenone and which have been overstocked, the growth rate will resemble that of the 1948 plant of fingerlings.

Production of the Lake in Pounds and Numbers. From Table 13 it may be seen that 1,853 pounds of brook trout were planted in Castle Lake in 1947 and 1948 and during the period 1947-54, inclusive, 3,767 pounds of brook trout were removed.

TABLE 12

Catch per Year in Pounds of Each of the Plants of Brook Trout

	Not marked	RV	Ad	Ad-LV	Wild fish
1947	592				----
1948	305	110			----
1949	51	261	42	49	----
1950	30	194	154	176	----
1951		141	137	154	69
1952		109	71	76	200
1953		47	20	26	257
1954		27	8	10	451
Totals	978	889	432	491	977

TABLE 13

	Wt. of fish planted	Wt. of fish removed
1947—Yearlings	1,503 lbs.	978 lbs.
1947—Fingerlings	250	889
1948—Fingerlings	100	923
Wild Fish	----	977
Totals	1,853	3,767

Food habit studies of brook trout at Castle Lake prior to 1947 indicated that the species is generally nonpiscivorous, so this mortality factor becomes negligible and survival is high. In addition, we have shown that when brook trout alone are present in Castle Lake, natural reproduction results in a significant addition to the catch. In fact, we have observed in other, less heavily fished lakes, that an initial stocking of brook fingerlings will result in a self-maintaining population. Despite the fact that brook trout alone will yield a large number of fish, the total poundage and the average size of the fish are smaller than when rainbow are also present.

Referring to the situation which existed in Castle Lake prior to chemical treatment, it does not appear that a gain in crop per acre per year could be made by introducing brown trout. Actually, the number of fish surviving to the creel would be considerably reduced. However, the average size of fish caught would be increased and frequently this factor alone will warrant the planting of brown trout.

In conclusion, it appears that most California lakes of the Castle Lake type are being managed reasonably well at present.

The 1947 plant of 20,000 yearling brooks was unprofitable. Of the 1,503 pounds put in the lake, only 978 pounds were removed by fishermen.

The fingerling plants were much more productive, though there was a considerable difference between the fingerling plants of 1947 and 1948. Apparently the shortage of food was responsible for the lower production from the 1947 group of fingerlings. The weight of trout removed from the 1947 plant was 3.5 times the weight of fish planted, whereas the weight of the 1948 group removed was 9.2 times the

weight planted. This difference is not due entirely to a higher survival of the 1948 group; in fact, this had but very little effect. The important difference was in the growth of the 1948 plant and the only explanation which can be offered is the presumed increase in food.

The average annual yield of brook trout prior to the introduction of rainbow in 1952 was 493 pounds, or 10.3 pounds per acre. For the period 1947-54 the yield per acre was 9.8 pounds. The annual yield per acre after rainbow were introduced in 1952 was considerably greater than 10.3 pounds. Therefore, we may assume that Castle Lake is more productive of trout with the two species than with brook trout alone (or that there was a gradual improvement in food supply).

Food habit studies performed prior to chemical treatment in 1946 showed that the food preferences of the two species were much alike. However, their foods were not identical and this is presumed to be the reason why Castle Lake can support more pounds of brook and rainbow than brook trout alone. In the years 1943-45, inclusive, prior to chemical treatment, the average catch per acre was 10.4 pounds. At that time the lake was supporting a considerable number of brown and lake trout. These became primarily piscivorous as they aged and since both were difficult for the anglers to catch it is assumed that their predation upon the brooks and rainbow converted these more available species to less available ones. Eventually these older browns and lake trout died, without increasing the angler's catch.

From the foregoing we postulate that following chemical treatment in lakes of the Castle Lake type the greatest yield from the standpoint of numbers can be achieved by planting brook trout alone.

TABLE 14

Total Annual Catch of Brook Trout

	Number of fish	Total pounds	Average weight (pounds)
1947	5,765	592	0.103
1948	5,190	415	0.080
1949	4,334	403	0.093
1950	5,255	554	0.105
1951	2,674	501	0.187
1952	2,180	456	0.209
1953	1,828	350	0.191
1954	2,475	496	0.200
Totals	29,701	3,767	0.127

RECOMMENDED MANAGEMENT PRACTICES

1. In lakes with adequate springs for brook trout spawning, either brook trout alone or brook trout and rainbow should be planted. Natural reproduction of the brooks will appreciably reduce the cost of maintaining good fishing.

2. In lakes lacking adequate springs for spawning, it is less important that brooks be planted. If nearby lakes with suitable spawning grounds for brooks are present, it may be preferable to stock the lakes lacking such areas with rainbow alone.

3. If good spawning tributaries are present, at least in the spring, it is best to stock with a spring-spawning strain of rainbow alone.

4. If public demand requires a larger trout, brown trout alone should be planted.

5. When brown trout are already present in appreciable numbers the survival of fingerling brook or rainbow is so low that their introduction seems undesirable.

6. Stocking with yearling brook trout appears to be unjustified. Excellent brook trout fishing can be achieved more economically by planting fingerlings.

7. The Castle Lake study has not established the number of fingerling brook trout which should be planted per acre. Much variation presumably exists in the optimum stocking rate from lake to lake, depending largely upon available food, the number of predators, and the intensity of fishing.

8. In the present study, chemical treatment has been shown to be highly effective in increasing the survival to the creel of planted brook trout fingerlings, but under the conditions of this study it does not appear that the crop per acre per year is greater when brook alone are present than when four species of trout were present. However, it now appears that a combination of brook and rainbow may permit the highest yield.

SUMMARY

The present report covers the eastern brook trout phase of the Castle Lake investigation and the results are compared with those presented in the 1946 report "Castle Lake Trout Investigation. First Phase: Interrelationship of Four Species."

During this portion of the investigation, covering the period 1947-54, inclusive, the results from planting brook trout have been markedly different from those which were obtained prior to 1946, when the lake was treated with rotenone and all four species of trout removed.

In 1947 both brook trout yearlings and fingerlings were planted and in 1948 more fingerlings were planted, giving a total of 60,000 fish. The present report is based upon the returns to anglers of these fish during the ensuing eight years.

During the three years 1949-51 no trout were planted in Castle Lake. In 1952 the first of a series of rainbow trout plants was made and in the years 1952-54 both brook and rainbow trout were caught. As late as 1954 some of the marked brook trout planted in 1947 and 1948 were being caught but most were naturally spawned in the spring areas of the lake bottom.

The yearling brook trout planted in 1947 were of "subcatchable" size, averaging 13 per pound. However, many were larger than this and catches were heavy from the time of liberation. This group contributed to the catch for at least four years and the total return to the fishermen was 48.3 percent.

The fingerlings planted in 1947 and 1948 were caught during seven seasons following the liberations and the final returns were 34.6 and 36.4 percent, respectively.

The removal of the highly predatory brown and lake trout in 1946 increased the survival of the fingerling brook trout to the anglers' catch

from an average of 1.9 percent to approximately 35 percent. The survival of the yearling brook trout was not markedly affected. Before the lake was treated their survival was 40 percent, while following treatment it was 43.8 percent.

The 1948 plant of fingerlings was divided, with one half marked by removal of the adipose fin alone and the other half by removal of the adipose and left ventral. During the ensuing seven years 34.1 percent of those with the adipose removed were caught, while the other group contributed 38.7 percent. We may conclude that removal of a ventral fin and the adipose does not cause a greater mortality than removal of the adipose fin alone. Similarily, the growth rates of the two groups were practically identical.

Following treatment of Castle Lake with rotenone, the food supply was reduced. This, together with overstocking in 1947, caused the yearlings to grow slowly and to have a low condition factor. The growth of the fingerlings planted in 1947 was slower than that of the fingerlings stocked in 1948. The average fork length of all brook trout caught during the period 1947-54, inclusive, was 7.0 inches. Few of the fish reached a foot in length and the largest taken was 18.4 inches long.

In common with many similar lakes in California, an initial planting of brook trout resulted in a self-propagating population which by itself provided moderately good fishing. In 1954, 84 percent of the catch was composed of brook trout, nearly all of which were naturally spawned.

Although 1,503 pounds of yearling brook trout were planted in 1947, only 978 pounds of fish from this plant were eventually caught by anglers. In marked contrast, 100 pounds of brook fingerlings planted in 1948 yielded 923 pounds caught by anglers.

In computing the following costs for each fish caught by anglers in Castle Lake, it is estimated that the fingerlings cost one cent and the yearlings 15 cents each at planting time.

	Planted as fingerlings	*Planted as yearlings*
Prior to treatment	$0.525	$0.375
After treatment	0.03	0.35

The average annual yield of brook trout to the anglers prior to the planting of rainbow was 493 pounds, or 10.3 pounds per acre.

It is already evident that the yield in pounds per acre following the planting of rainbow in 1952 will be considerably greater than it was when brooks alone were planted.

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AN EVALUATION OF CREEL CENSUS METHODS [1]

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INTRODUCTION

The creel census has long been recognized as a primary tool of fisheries research. However, a complete census on any water, although reliable, is costly, while the cheaper partial check is often inadequate.

Operators of dawn-to-dark and seven-day-per-week creel checks cannot receive adequate time off without the provision of relief personnel. Although regular operators for creel census duty can usually be obtained readily, it is often difficult to find auxiliary personnel for relief periods.

For several years some of our long-term projects have made complete creel checks. It was believed that the substitution of well-designed partial censuses might result in substantial administrative and operational benefits without an undue sacrifice of accuracy.

In any partial creel census three criteria—representativeness, adequacy, and cost—must be considered (Mottley and Embody, 1940). Cost can be determined readily. However, the other two factors are influenced by many variables, such as weather, erratic concentrations of fishing effort, variations in availability (to the angler) of various species of fishes, and hatchery planting schedules.

This paper describes four partial census methods and the results that may be expected from them.

Acknowledgment is due J. H. Wales, Associate Fisheries Biologist, who directed and conceived the study, and Paul E. Giguere, Assistant Fisheries Biologist, who provided considerable editorial assistance.

METHODS

Data from creel checks at Castle Lake, Siskiyou County (Wales and German, 1956), and Rush Creek, Mono County (Vestal, 1954), were conveniently available. These records included the number of fish in the individual creels; the length, weight, and marks of each fish; anglers' names, and other pertinent data.

It was a comparatively simple matter to conduct a hypothetical creel census by drawing from these data the records for any pre-selected combination of days. The results could then be evaluated by comparison

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with the actual figures. In this way the four proposed techniques listed below were evaluated.

1. An unstratified random sample of 40 days from the entire season.
2. A sample stratified by calendar months, with the restriction that each day of the week be sampled once and only once each month. A total of 42 days was sampled by this method.
3. A sample of 40 days stratified by week days and week-end days plus holidays.
4. A sample of five days per week, with the restrictions that all week ends and holidays be sampled and no particular day be missed on two consecutive weeks. With this method 133 days were censused.

In a large part of California the trout season begins on the Saturday nearest May 1st and extends through October 31st. Accordingly, the season varies in length from 181 to 187 days. The first three methods sampled slightly more than 20 percent of the season, while the fourth included more than 50 percent.

DISCUSSION OF METHODS

Method No. One. Unstratified Sample (1953 Rush Creek data).

Each day of the season was numbered in chronological order from 1 to 183. The 40 days to be censused were then selected by use of a table of random numbers (Dixon and Massey, 1951). The circled days in Figure 1 indicate those selected by this method. Ten days were sampled during May, when fishing pressure is moderate. Yet in July and August, the peak of the vacation season and fishing effort, only four and five days, respectively, were sampled.

MAY

					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

JUNE

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

JULY

			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

AUGUST

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

SEPTEMBER

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

OCTOBER

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

FIGURE 1. The days selected for the census in the unstratified sample.

Method No. Two. Stratification by Calendar Months (1953 Rush Creek data).

In order to obtain a more even distribution of sampling, the season was stratified into the six calendar months of the fishing season with the restriction that each day of the week was to be sampled once and

only once each month. Thus, 42 days were sampled from the entire season. Once again, a table of random numbers was employed in the selection. In this instance, the days of each month were numbered 1 to 30 or 31 and each month was treated separately. The results of the selection are shown in Figure 2 (census days circled).

MAY

					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

JUNE

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

JULY

			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

AUGUST

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

SEPTEMBER

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

OCTOBER

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

FIGURE 2. The days selected for the census in the sample stratified by calendar months.

Method No. Three. Stratification by Week Ends and Weekdays (1953 Rush Creek data).

A total of 40 days was sampled from a season stratified by periods of weekdays and week ends plus holidays. The fraction $^{54}/_{183}$, the number of week-end days plus holidays over the total number of days

MAY

					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

JUNE

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

JULY

			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

AUGUST

						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

SEPTEMBER

		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

OCTOBER

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

FIGURE 3. The days selected for the census in the sample stratified by week ends and weekdays.

in the season, represented the sampling ratio. Thus by proportionality the forty days to be selected consisted of 12 drawn from week ends or holidays and 28 from weekdays. Each group was then numbered and selected separately by the random numbers method. The circled days in Figure 3 illustrate the sampling distribution.

Method No. Four. Five Day per Week Check (1953 Rush Creek and Castle Lake data).

This plan had the restriction that all week ends and holidays must be checked and that no particular day could be missed on two consecutive weeks. Whenever possible, the checker would be permitted two consecutive days off. With this system, 133 of the 183 days in the season were sampled. In Figure 4 the days *not* checked are cross-hatched.

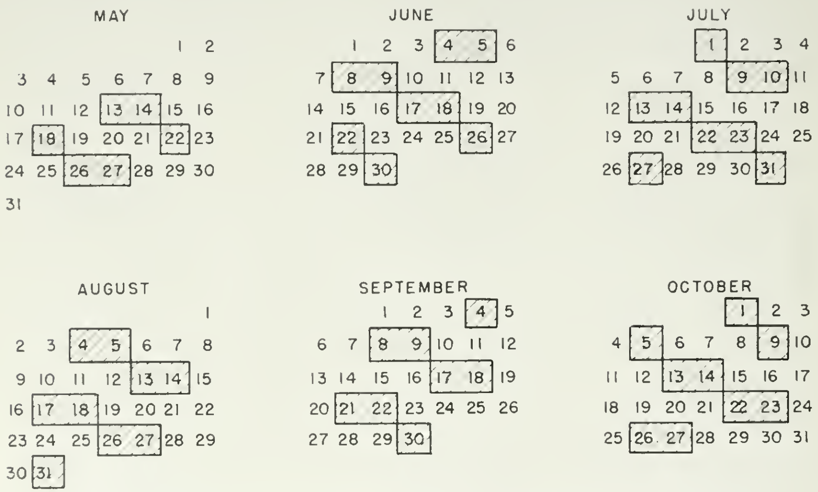

FIGURE 4. The days off during the five-day-per-week sample are cross-hatched.

Estimates for non-census days were obtained by averaging the results of the same day in the previous and subsequent weeks. For example, the average of May 6 and 20 was used to estimate the catch and effort for May 13.

If a holiday fell on a day that would normally have been taken off, the restrictions imposed by this census method made it necessary to check that day. This meant that six days would be sampled during certain weeks.

The census was conducted every day of the opening week, in order to provide data for averages used the following week. It would appear to be well to use this same plan for the last week of the season. However, our data indicate that the fishing pressure is so slight by the last week in October that a full seven-day check is not worthwhile. Upon this occasion the totals from the previous week were substituted for the particular days taken off, i.e., the totals for October 19 and 20 were used again on October 26 and 27.

RESULTS

Table 1 contains a summarization of hypothetical and actual creel censuses at Rush Creek and Castle Lake (1953 data). As might be expected, the theoretical results of the fourth method, with its much larger sample size, most closely approximate the actual figures.

TABLE 1

Estimated and Actual Season Totals *

Method	Number anglers or angler days	Number of hours fished	Marked fish caught	Fish caught	Fish per hour
No. 1	2,040 (2,060)	5,909 (5,632)	1,230 (955)	2,173 (1,773)	0.37 (0.32)
No. 2	1,865 (2,060)	4,794 (5,632)	666 (955)	1,203 (1,773)	0.25 (0.32)
No. 3	2,118 (2,060)	5,931 (5,632)	814 (955)	1,528 (1,773)	0.26 (0.32)
No. 4(a)	2,039 (2,060)	5,521 (5,632)	962 (955)	1,725 (1,773)	0.31 (0.32)
No. 4(b)	1,488 (1,429)	4,817 (4,782)	4,086 (3,988)	4,086 (3,988)	0.84 (0.83)

* Actual totals are given in parentheses. Nos. 1-4(a) are based upon data collected at the Rush Creek test stream in 1953. No. 4(b) is the same method as 4(a), but is based upon Castle Lake creel census data for 1953.

The first method provided compatible estimates of angling effort. However, catch estimates were much in excess of the known totals. Despite the more uniform distribution of selected days, the second and third methods grossly underestimated the catch.

A better idea of the magnitude and direction of the deviations between the true and theoretical creel census returns is afforded by a conversion of the data in Table 1 to percentages of deviation. The transformation appears graphically in Figure 5. The percentages of deviation were computed by dividing the difference between the known and actual totals by the known total and multiplying the quotient by 100. Overestimates and underestimates are indicated by plus and minus signs.

The 1954 data from Rush Creek were treated in the same manner. The results of the four methods applied to the 1954 data also appear in Figure 5. It can be readily seen that there is considerable variation from one year to the next, regardless of the census method used.

In the 1954 data the deviations for the five-day census were as high as 12 percent. These relatively large deviations are attributed to light fishing pressure and relatively few good catches. The brown trout (*Salmo trutta*) now stocked in Rush Creek are particularly adept at eluding the average California angler. Consequently, the inclusion or exclusion of a good catch has considerable bearing on the total when the work is projected to represent the entire season.

It is apparent that for waters subject to considerable daily fluctuations in fishing pressure, the sampling of creels must occur on a large number of days. Only five limit catches were recorded from a total of 2,060 creels checked at Rush Creek during the 1953 season. All five limits were taken in the first two months of the season and could have been easily missed with a partial creel check.

The evaluation of these partial census techniques indicated that the five-day-per-week method may be used with satisfactory reliance, and

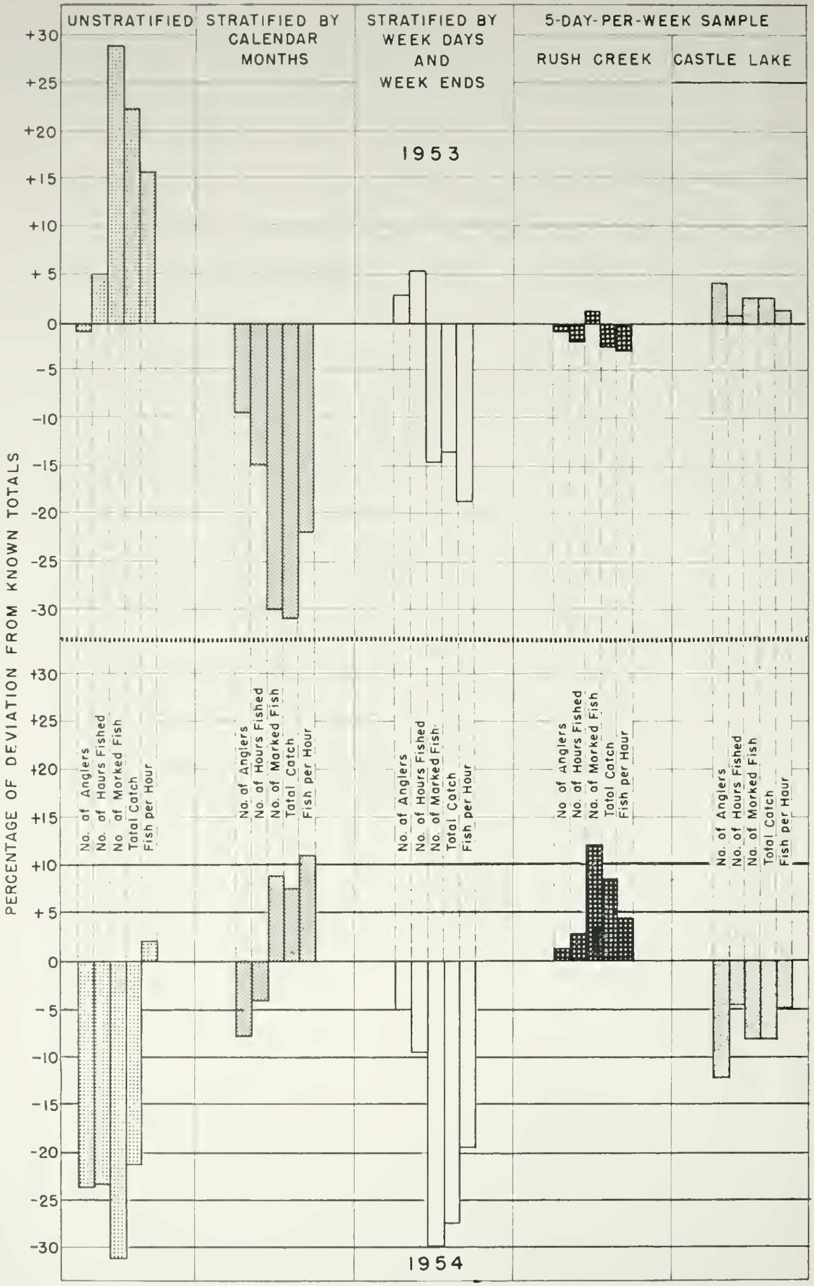

FIGURE 5. Deviations from known totals of statistics derived from the hypothetical partial census.

moreover, eliminates the cost and need of two working days each week of the census.

SUMMARY

In lakes and streams in which fishing pressure is relatively light, partial creel censuses which include less than 25 percent of the fishing days may not yield entirely adequate data.

The present study indicates that when monetary or other considerations limit the number of census days to approximately 40 in a six-month angling season, the best over-all coverage of the entire season will be obtained from a creel census involving stratification by calendar months (Method No. 2 in the present paper).

A five-day-per-week check which includes all week ends and holidays will provide more accurate results. Even this more intensive survey of angling activity may yield estimated totals that deviate as much as 12 percent from the known totals.

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A WATERFOWL NESTING STUDY ON THE GRASSLANDS, MERCED COUNTY, CALIFORNIA[1]

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INTRODUCTION

During the spring and summer of 1953 and 1954, a waterfowl nesting survey was conducted on the Grasslands of Merced County, California, by Pittman-Robertson Project W-30-R.

The Grasslands, an area comprising somewhat over 90,000 acres, lie west of the San Joaquin River, between the towns of Newman and South Dos Palos. The great majortiy of this land is flooded during fall and winter and used for waterfowl shooting by over 150 gun clubs. During the rest of the year the principal land use is cattle grazing, wherever irrigation water is available at sufficiently low price to make it profitable. The area formerly ranked as one of the best duck nesting regions in the Central Valley because of the natural overflow of the San Joaquin River, which annually flooded portions of the Grasslands during the winter and spring, leaving sufficient water to maintain ponds and marshes throughout the year.

With the advent of intense agriculture in the San Joaquin Valley, the diversion of more and more water for irrigation of croplands has resulted in a serious reduction of suitable nesting habitat in the Grasslands. Although a great many wells have been drilled by cattlemen and gun club owners, they have not contributed appreciably to any restoration of waterfowl habitat.

The only prior comprehensive duck nesting study undertaken in this area was made in 1948 by A. W. Miller of the California Department (then Division) of Fish and Game. In 1953 it was decided that a comparable survey should be made to determine any changes affecting waterfowl production during the intervening five years.

METHODS

Except for a few modifications necessitated by special conditions, such as particular types of terrain, the methods employed in collecting the pertinent data were the same as those used by the project in other nesting studies (Miller and Collins, 1954; Hunt and Naylor, 1955).

Each located nest was marked by a willow stake placed several yards from the nest and related to a prominent landmark. A Unisort Analysis Card was used to record the history of each nest; the stake and card

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bore corresponding numbers to facilitate relocation of the nest. As nearly as possible, nests were visited once every seven days. Often active nests were located by dragging a 100-foot length of rope between two men, thereby flushing the hens from the nests, but generally it was necessary to inspect all available nesting cover to insure the location of any nests already hatched or destroyed.

Since it was physically impossible for two men to search the entire Grasslands, certain study plots were chosen in different parts of the area. These plots are not claimed to be representative of the entire area with respect to density of nests, since thousands of acres were devoid of water and nesting cover. Because it was considered desirable to study a fairly large sample of duck nests, only plots which appeared to be reasonably productive were selected.

In 1953 four such study plots were chosen: (1) A portion of the Gustine Gun Club, 1,310 acres situated about five miles southeast of Gustine. (2) A portion of Los Banos Waterfowl Management Area amounting to approximately 500 acres. This area is located about four miles northwest of Los Banos. (3) Part of the Potter Ranch lying between the San Joaquin River and Chamberlain Slough. This plot contained around 500 acres and was situated 12 miles east of the Los Banos Waterfowl Management Area. (4) The Britto plot, four miles northwest of South Dos Palos, composed of portions of several small gun clubs, all in the vicinity of the Britto Oil Pumping Station. This plot contained 460 acres.

In 1954 the vegetative cover on the Potter Ranch was too poor and thin to attract nesting ducks. A thorough search during the peak of the season failed to reveal a single duck nest. On the Gustine Club the study plot was increased to 2,000 acres, on the Los Banos Waterfowl Management Area to 1,000 acres, and on the Britto plot to 800 acres.

The Gustine Club, located in the most favorable part of the Grasslands, supports a variety of vegetation. Hundreds of acres are more or less densely covered with wire rush (*Juncus balticus*), which proved to be a favorite nesting cover for the local breeding population of ducks. A large slough bordered by cattails (*Typha*) and bulrushes (*Scirpus*) has water throughout the year. Considerable effort has been made by the stockmen to irrigate the pasture during the summer months, to provide succulent feed for their cattle. In 1953, 70.2 percent of the total sample of nests were located on the Gustine Club. In 1954, 83.5 percent were found on this plot.

Since one of the more important functions of the Los Banos Waterfowl Management Area is to alleviate waterfowl damage to rice grown in this section of the State, it is gradually being converted, wherever feasible, into crop production. Nesting cover consists only of small scattered patches of wasteland. No cattle were being grazed here, but there was a considerable amount of human activity in most parts of the area.

The Britto plot was selected as a sample from the southeastern part of the Grasslands. The cover was fairly satisfactory, but there was not enough water to attract many nesting ducks. There was a moderate amount of cattle grazing on this plot.

It is believed that less than 15 percent of all nests were missed on the Gustine Club, but a somewhat larger proportion may have been overlooked on the other plots, due to the nature of their terrain.

Many of the nests (25 percent in 1953, 50 percent in 1954) were already destroyed when found. Nests of this class are sometimes easily overlooked.

It was necessary to devise a method of correctly identifying destroyed nests. Fortunately, only five species of ducks were involved, and one of these, the cinnamon teal (*Anas cyanoptera*), could be identified readily by the smaller nest and eggs and the darker color of the down used in the nest lining. In the cases of mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), pintail (*Anas acuta*), and shoveller (*Spatula clypeata*) a few breast feathers were invariably included in the nest material. These were closely studied and compared and were found to constitute the most reliable distinguishing character.

FATE OF NESTS

During the 1953 study 319 duck nests and 20 coot (*Fulica americana*) nests were found, while 427 duck nests and 19 coot nests were located in 1954. The coot nests represented only a small sample, since no concerted effort was expended to locate them. They were found incidental to the search for duck nests.

Tables 1, 2, 3 and 4 show the fate of all duck nests included in the samples. The most significant fact revealed through this investigation was the high incidence of nest destruction by predatory mammals, 61.7 percent in 1953 and 82 percent in 1954. Since this cause of nesting failure appears to have increased alarmingly from the 35 percent destruction recorded in 1948 (A. W. Miller, unpublished report), it was considered of interest to determine which species of predators were responsible for most of this damage. The near absence of islands and the ready accessibility of all nest sites render these nests extremely vulnerable to interference by many different kinds of animals, including dogs, cat, raccoons (*Procyon lotor*), skunks (*Mephitis mephitis* and *Spilogale gracilis*), and opossums (*Didelphis virginiana*). In one instance, in 1953, a gopher snake (*Pituophis catenifer*) was surprised while coiled on top of the eggs in a mallard nest. However, snakes are known to swallow the eggs whole, and in virtually every case of predation the broken shells were found in or about the nests, in some instances several yards away, indicating some other agent.

Eventually photography was resorted to in order to obtain reliable proof of the cause of at least some of the predation. The photographic work was begun in the summer of 1953 and continued in 1954. The camera with synchronized flash was set up and focused on a destroyed nest supplied with replacement eggs from a deserted nest. A wire connected the camera shutter with the eggs in such a way that a pull exerted on any one of the eggs would trip the shutter. Through this method (and much trial and error!) a series of photographs showing skunks and opossums in the act of destroying the eggs was obtained (see Figures 1 and 2).

No success was had in photographing a raccoon in action but it is believed this intelligent animal was too wary to go near the camera. In the case of one destroyed nest raccoon tracks leading to and from the nest were plainly visible in the soft mud.

TABLE 1

Fate of Nests by Species—1953

Species	Destroyed by predatory mammals		Destroyed by cattle		Flooded		All eggs infertile		Deserted		Hatched		Totals	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Mallard	130	63.7	12	5.9	11	5.4	1	0.5	20	9.8	30	14.7	204	100
Gadwall	24	64.9	3	8.1	2	5.4	0	0	2	5.4	6	16.2	37	100
Cinnamon Teal	39	55.7	3	4.3	6	8.6	1	1.4	7	10.0	14	20.0	70	100
Pintail	4	66.7	0	0	0	0	0	0	0	0	2	33.3	6	100
Shoveller	0	0	0	0	2	100	0	0	0	0	0	0	2	100
Totals	197	61.7	18	5.6	21	6.6	2	0.6	29	9.0	52	16.3	319	100

TABLE 2

Fate of Nests by Species—1954

Species	Destroyed by predatory mammals		Destroyed by cattle		Flooded		All eggs with dead embryos		Deserted		Hatched		Totals	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Mallard	246	80.4	6	2.0	1	0.3	0	0	18	5.9	35	11.4	306	100
Gadwall	48	82.7	1	1.7	0	0	1	1.7	4	7.0	4	7.0	58	100
Cinnamon Teal	50	89.3	2	3.6	2	3.6	0	0	1	1.8	1	1.8	56	100
Pintail	6	100	0	0	0	0	0	0	0	0	0	0	6	100
Redhead	0	0	0	0	0	0	0	0	1	100	0	0	1	100
Totals	350	82.0	9	2.1	3	0.6	1	0.2	24	5.6	40	9.4	427	100

TABLE 3

Fate of Nests by Study Plots—1953

Plot	Destroyed by predatory mammals		Destroyed by cattle		Flooded		All eggs infertile		Deserted		Hatched		Totals	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Gustine Club	133	59.4	18	8.0	19	8.5	1	0.4	20	9.0	33	14.7	224	100
Los Banos Area	31	86.1	0	0	1	2.8	0	0	2	5.6	2	5.6	36	100
Potter Ranch	4	33.3	0	0	0	0	0	0	3	25.0	5	41.7	12	100
Britto	29	61.7	0	0	1	2.1	1	2.1	4	8.5	12	25.5	47	100
Totals	197	61.7	18	5.6	21	6.6	2	0.6	29	9.0	52	16.3	319	100

TABLE 4

Fate of Nests by Study Plots—1954

Plot	Destroyed by predatory mammals		Destroyed by cattle		Flooded		All eggs with dead embryos		Deserted		Hatched		Totals	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Gustine Club	294	82.6	7	2.0	1	0.3	1	0.3	18	5.1	35	9.8	356	100
Los Banos Area	25	80.6	1	3.2	0	0	0	0	2	6.5	3	9.7	31	100
Britto	31	77.5	1	2.5	2	5.0	0	0	4	10.0	2	5.0	40	100
Totals	350	82.0	9	2.1	3	0.6	1	0.2	24	5.6	40	9.4	427	100

FIGURE 1. An opposum in the act of preying on a duck nest. *Photograph by the author.*

The kinds of birds that came within the scope of this study were by no means the only victims of nest predators. Ring-necked pheasants (*Phasianus colchicus torquatus*) were subject to heavy predation. Every nest found of bitterns (*Botaurus lentiginosus*) and many of meadowlarks (*Sturnella neglecta*), black terns (*Childonias nigra*), shorebirds (*Scolopacidae*), and even marsh hawks (*Circus hudsonius*) were preyed upon.

No instance of predation by birds was definitely known to have occurred. Ring-billed gulls (*Larus delawarensis*), crows (*Corvus brachyrhynchos*), and ravens (*Corvus corax*) were seldom seen, and yellow-billed magpies (*Pica nutalli*), although abundant, rarely ventured far away from the vicinity of trees.

Since cattle grazing is of great economic importance in the Grasslands, it was gratifying that very few duck nests were stepped on or otherwise destroyed directly by cattle. Some nests, no doubt, became more exposed to predators because of trails made by livestock. However, this did not appear to be an important factor from a comparison between the plots which were moderately grazed and a plot without grazing.

In 1953 flooding caused 6.6 percent of the nests to be unsuccessful. It amounted to 8.5 percent on the Gustine Club, where pastures were irrigated several times during the season. In many instances the hens were noticed to have raised their nests several inches in attempts to

FIGURE 2. A striped skunk in the act of preying on a duck nest.
Photograph by the author.

avoid inundation. This was accomplished by piling any available material over the top of the down lining and somehow managing to get the eggs up through this new bottom. In other words, if the water did not rise too rapidly flooding of the pasture did not necessarily prove disastrous to the nest. This adaptive behavior was observed in mallard, gadwall, and cinnamon teal.

In 1954 nest failures due to flooding were negligible, since low priced water was not available and consequently there was very little irrigation. Indeed, 43 percent of all duck nests were located at least 100 yards from the nearest water.

Nine percent of all duck nests found during the 1953 season were deserted for no discernible reason, but only 5.6 percent fell in this category in 1954. It must be remembered, however, that correspondingly greater percentage of active nests was found in 1953 than in 1954.

Table 5 shows the fate of the eggs in the hatched nests. In 1953, 52 successful nests produced a total of 420 eggs, of which 76.9 percent hatched for an average of 6.2 eggs per nest. In 1954, 40 successful nests produced a total of 340 eggs, of which 74.4 percent hatched for an average of 6.3 eggs per nest.

TABLE 5

Fate of Eggs in Hatched Nests

	Season	
	1953	1954
Percentage destroyed	1.9	4.1
Percentage with dead embryos	8.1	8.5
Percentage missing	6.4	6.2
Percentage infertile	6.7	6.5
Percentage dead in nest	0	0.3
Percentage hatched	76.9	74.4
Totals	100	100

NESTING PERIODS

Although a few mallards have been known to start nesting activities as early as late February, the present survey was not begun until late April. However, since all active nests were included in the study it is believed that the fate was determined for the relatively small number of early nests.

Tables 6 and 7 show by 10-day periods the numbers of active nests located from the time the study was initiated until the end of the nesting season. It seems reasonable to assume that renesting may account for the long period over which new active nests, especially those of mallard, were located. Since there is little doubt that ducks renest in the event the first nesting is interrupted, the present survey could scarcely serve as an index to the total nesting population.

Tables 8 and 9 show the number of duck nests hatching in each 10-day period. Those nests which were found to have hatched previous to the time of discovery are not included in these tables for the obvious reason that the hatching period was not known. The excessive amount of predation rendered it impossible to determine the normal peak of hatch.

NEST SITES AND COVER

Nest sites all fell into one of the following four categories: (1) dikes and road shoulders; (2) islands; (3) pastures; (4) fallow land or wasteland (usually fields or meadows where no stock was being grazed). The term "island" is used in a rather broad sense, generally denoting a mere hummock surrounded by shallow water during the nesting period. During the dry conditions of 1954 there were few such situations.

Most of the nests were located in open fields or pastures, where the cover consisted largely of wire rush. The nests were usually well concealed at the beginning of the incubation period but tended to become exposed later, as the vegetation dried and fell over or was trampled by cattle. The most unorthodox nest site was encountered in 1953, when a mallard built her nest on the ground in a willow thicket in the midst of a thriving heron rookery. Statistics relating to nest sites, cover, and

TABLE 6
Period in Which Active Nests Were Located in 1953

Species	April 12	April 23	May 3	May 13	May 23	June 2	June 12	June 22	July 2	July 12	July 22	Totals
Mallard	3	13	25	32	25	24	11	12	5	1		151
Gadwall				3	2	6	3	5	3			22
Cinnamon Teal				10	3	11	7	8	2	2		43
Pintail			1	1	2	1						5
Shoveller				2								2
Totals	3	13	26	48	32	42	21	25	10	3		223

TABLE 7
Period in Which Active Nests Were Located in 1954

Species	April 12	April 23	May 3	May 13	May 23	June * 2	June * 12	June * 22	July 2	July 12	Totals
Mallard	2	31	38	21	28	17		5			142
Gadwall			3	4	5	1	1	4	1		19
Cinnamon Teal			6	8	3	1		2			20
Pintail					2	1					3
Redhead			1								1
Totals	2	31	47	34	38	20	1	11	1		185

* Personnel away from project most of period June 12 through June 22.

TABLE 8

Hatching Period—1953 (Active Nests Only)

Species	May		June			July			August	Totals
	13	23	2	12	22	2	12	22	1	
Mallard	2	4	2	8	2	5	2			25
Gadwall				1			2	1		4
Cinnamon Teal			2	2	2	2	3	1		12
Pintail		2								2
Totals	2	6	4	11	4	7	7	2		43

TABLE 9

Hatching Period—1954 (Active Nests Only)

Species	April	May			June			July			Totals
	23	2	12	22	2	12	22	2	12	22	
Mallard	2	1	6	5	6	1		2			23
Gadwall					2				1		3
Totals	2	1	6	5	8	1		2	1		26

distance of the nest to the nearest water are summarized in Tables 10, 11, and 12. The distance to water as given in Table 12 refers to the distance at the time the nest was found and is, of course, extremely variable. However, Table 12 does illustrate the fact that much drier conditions existed during the summer of 1954 than that of 1953.

TABLE 10

Nest Sites (Percentages of Nests Found at Each Site)

Season	Dike	Island	Pasture	Wasteland	Totals
1953	2	10	73	15	100
1954	1	3	89	7	100

TABLE 11

Cover (Percentages of Nests Found in Each Cover Type)

Season	Wire Rush	Grasses	Bulrush	Cattails	Other	Totals
1953	87	12	0	0	1	100
1954	83	4.7	0.5	0.2	1.6	100

TABLE 12

Distance From Water (Percentages of Nests in Each Category)

Season	0 yards or over water	Up to 3 yards	3 to 50 yards	50 to 100 yards	Over 100 yards	Totals
1953	7	13	66	8	6	100
1954	3	6	20	28	43	100

BROOD DATA

In a region with very little open water and where much time was spent searching for nests quite far from any water, the observers were able to obtain only meager brood data. During the summer of 1954, 32 broods of various age groups were observed on the study plots, of which 21 were mallard broods, 4 gadwall, 4 cinnamon teal, 2 pintail, and 1 ruddy duck. The number of young in these broods averaged 5.7.

COOTS

A sample of 20 coot nests was studied in 1953, while 19 nests were studied in 1954. These nests were found to be rather poorly concealed in comparison with duck nests, but on the other hand they were invariably constructed in marshy situations in cattails or rush cover and generally over water. Table 13 compares the hatching success of coots in 1953 and 1954. It is believed that the notable difference in success in the two seasons is due to the fact that in 1953 the birds attempted to

nest in flooded fields, where water levels usually dropped before incubation was completed, while in 1954 nesting activities were virtually confined to canals, ditches, and sloughs, where water levels were relatively stable.

TABLE 13
Fate of Coot Nests

Season	Percentage destroyed	Percentage deserted	Percentage hatched	Percentage Total	Number of nests
1953	85	5	10	100	20
1954	32	5	63	100	19

CONCLUSIONS

Now that this investigation has brought out the fact that nesting failure of ducks in the Grasslands, due to predation, has increased at an alarming degree since 1948, the logical question arises: what can be done to remedy or improve this situation?

To this question there is probably no ready answer. A predator control program spread out over such a large area would certainly be expensive, and there is no guarantee that it would be effective. The increasing scarcity of water during the summer months has proved to be extremely detrimental to the ducks by (1) rendering their nests and eggs more vulnerable to attacks by various predators, (2) lessening the chances for survival of the few young which are produced, and (3) causing a marked decrease in the available food supply. At the same time, this drying up of the country has probably made the habitat more desirable for such predators as skunks and opossums.

It is suggested that if provisions could be made to supply adequate water throughout the nesting season to selected areas where cover and other conditions are especially favorable for nesting ducks, a limited predator control program could be focused on these areas.

SUMMARY

1. During 1953 and 1954 a waterfowl nesting survey was conducted on the Grasslands of Merced County, California, by Pittman-Robertson Project W-30-R. The Grasslands, covering over 90,000 acres, were formerly an excellent duck-producing area, but diversion of water for agricultural use has resulted in a serious reduction of suitable nesting habitat.
2. Sample plots with a combined area of 2,270 acres were selected in 1953. A total area of 3,800 acres was included in the study in 1954.
3. The common nesting species of ducks were mallard, gadwall, and cinnamon teal. A few pintails, shovellers, redheads, and ruddy ducks also nested within the area.
4. Duck nests numbering 319 were located and studied in the 1953 season. Of this number only 16.3 percent hatched. These successful nests averaged 6.2 hatched eggs per nest. Duck nests totaling 427

were studied in 1954, when the number of hatched nests was even lower, 9.4 percent. These averaged 6.3 hatched eggs per nest.

5. The principal cause of nesting failure was predation by mammals, which in 1953 accounted for the fate of 61.7 percent and in 1954 for the fate of 82 percent of all duck nests. In 1953, 25 percent and in 1954, 50 percent of all nests had been destroyed before they were located. Photographic evidence showed that skunks and opossums were responsible for most of the predation. Evidence indicated that raccoons also play a part in nest destruction.
6. Desertion, destruction by cattle, and flooding, in that order of importance, constituted the other main causes of nest failure.
7. Because of the excessive amount of predation in both seasons, it was not possible to determine the normal peak of nesting activity. Brood data were also meager.
8. The number of successfully hatched coot nests rose from 10 percent in 1953 to 63 percent in 1954.
9. As a means of increasing waterfowl production in the Grasslands, it is suggested that:
   a. Provisions be made during the nesting season to keep water on selected areas where nesting cover is adequate.
   b. A predator trapping program be concentrated on these selected areas.

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THE GREAT BASIN TENT CATERPILLAR IN RELATION TO BITTERBRUSH IN CALIFORNIA[1]

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INTRODUCTION

The Great Basin tent caterpillar (*Malacosoma fragile*) periodically defoliates and, under certain conditions, may kill bitterbrush (*Purshia tridentata*), a highly valued range browse. The value of bitterbrush for domestic grazing animals and big game, particularly deer, is well known. There are several current investigations of factors contributing to the decline of bitterbrush and the control of these factors in the management of bitterbrush ranges (Lassen et al., 1952; Dasmann and Blaisdell, 1954; Interstate Deer Herd Committee, 1954). Hormay (1943) discussed rodents, livestock grazing, deer grazing, defoliation by the tent caterpillar, burning, and weather as factors influencing growth and reproduction of bitterbrush.

The present report is concerned with the Great Basin tent caterpillar as one of the complex of factors Hormay discussed. The paper is intended to make available to those concerned with the management of bitterbrush ranges a summary of previously scattered information, as well as the results of current studies by the writer on the biology and economic importance of the insect. These studies are being made in conjunction with research into the use of micro-organisms as a possible control method of *M. fragile* (Clark and Thompson, 1954; Clark, 1955).

Most of the information presented here was collected in the eastside portion of California. Within this general area, tent caterpillar infestations have been particularly important in three rather well-defined localities (Figure 1). These are: the area between Mono and Crowley Lakes in Mono County, designated here as the "Mammoth Lakes area"; the Truckee Basin area, which extends 18 to 20 miles north from Lake Tahoe and 15 to 20 miles east from Donner Summit, largely in Nevada County; and the Modoc-Lassen area in the northeastern portion of the State, including Modoc and Lassen counties and parts of Shasta and Siskiyou counties.

BIOLOGY

Geographic Distribution

The Great Basin tent caterpillar, which was described by R. H. Stretch in 1881 from specimens collected near Virginia City, Nevada, is believed to be distributed in the general area between the Sierra Ne-

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vada-Cascade ranges and the Rocky Mountains (Keen, 1952). Recent observations by the writer, however, suggest that more than one species is involved in the eastern portion of this general distribution. In California, *M. fragile* occurs principally in the Transition Zone along the western slope of the Sierra Nevada-Cascade ranges and on the eastern side of this crest. On the western side of these ranges it is associated principally with species of *Ceanothus* and most commonly with snowbrush (or whitethorn), *C. cordulatus*. On the eastern side, it is most commonly found on bitterbrush.

Life Cycle in the Eastside Portion of California

The life cycle of *M. fragile* is similar in all respects to those of other members of the genus *Malacosoma*. Briefly, the larvae overwinter within the egg, the hatch occurs in the spring, and larval development

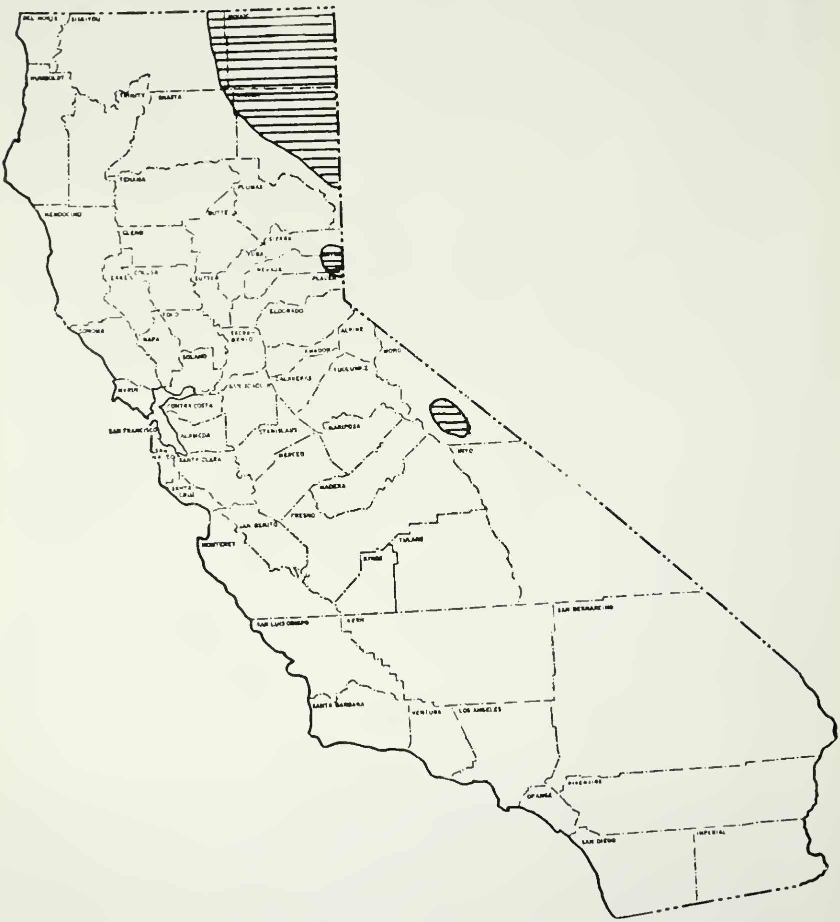

FIGURE 1. Areas in California (shaded portions) where the Great Basin tent caterpillar is of economic importance.

requires 40 to 70 days. Pupation, adult flight, and oviposition occur in mid- to late-summer.

The eggs are deposited in masses or bands around the smaller stems of the host plant in July, August, or September.[2] The egg masses frequently contain 100 to 140 eggs, although wider variation has been observed, and are covered with a dark, frothy, cement-like material for which Hodson and Weinmann (1945) proposed the term "spumaline" (Figure 2). The development of the embryo begins immediately after oviposition and is complete within three to five weeks. The first instar larvae or caterpillars (instar refers to the period or stage between molts and the instars are numbered to designate the various periods) then enter a diapause and pass the winter within the egg chorion.

The caterpillars hatch in the spring after the appearance of new leaves on the host plant. In the case of bitterbrush, the date of hatch coincides roughly with the formation of flower buds. This stage may be reached in early to late April in the Mammoth Lakes area, mid-April to early May in the Modoc-Lassen area, and mid-May to early June in the Truckee Basin area.

Immediately after hatching, the gray-black larvae cluster on the surface of the egg mass. Shortly thereafter, they move to the tip of the twig, where they begin feeding on the young foliage and start constructing the tent. The tent consists of layers of webbing around the tip of the twig. It is small and relatively inconspicuous for the first two or three weeks of development, and may be only an inch or two long. The tent is continually enlarged as the larvae develop and attains a length of five or six inches at larval maturity. In dense populations, larvae from different egg masses may join and construct tents over a foot long.

During early development, the caterpillars are highly gregarious. Individuals of a single brood are usually found concentrated on a single twig when feeding and on or in the tent during nonfeeding periods. This gregarious habit diminishes as the caterpillars develop, and the fifth, or final, instar larvae usually feed singly or in small scattered groups.

Four molts separate the five larval instars in the development of the larvae. During the course of this development, the dominant color of the larvae changes from the black or grayish-black of the newly hatched caterpillars to the yellow of the second and part of the third instars and then to the reddish-brown and red of the fourth and fifth instars.

Just prior to pupation, the mature larvae, which are $1\frac{1}{2}$ to 2 inches in length, become completely nongregarious. During this period they wander at random over the host and other plants or the ground and may be found several hundred feet from the nearest food. Pupation follows this random scattering, which may have a protective function in dispersing the immobile pupae. As a result of this wandering, cocoons of *M. fragile* are widely scattered over the site of an infestation. Although they occur in twisted leaves, attached to stems or twigs, or in the old tent, pupae are found most frequently under layered stems or debris at the ground surface. Transformation to the adult occurs within a yellow cocoon.

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[2] Since dates of occurrence of the various stages of development may vary with altitude, latitude, and seasonal variations in the weather, the dates given here are approximate.

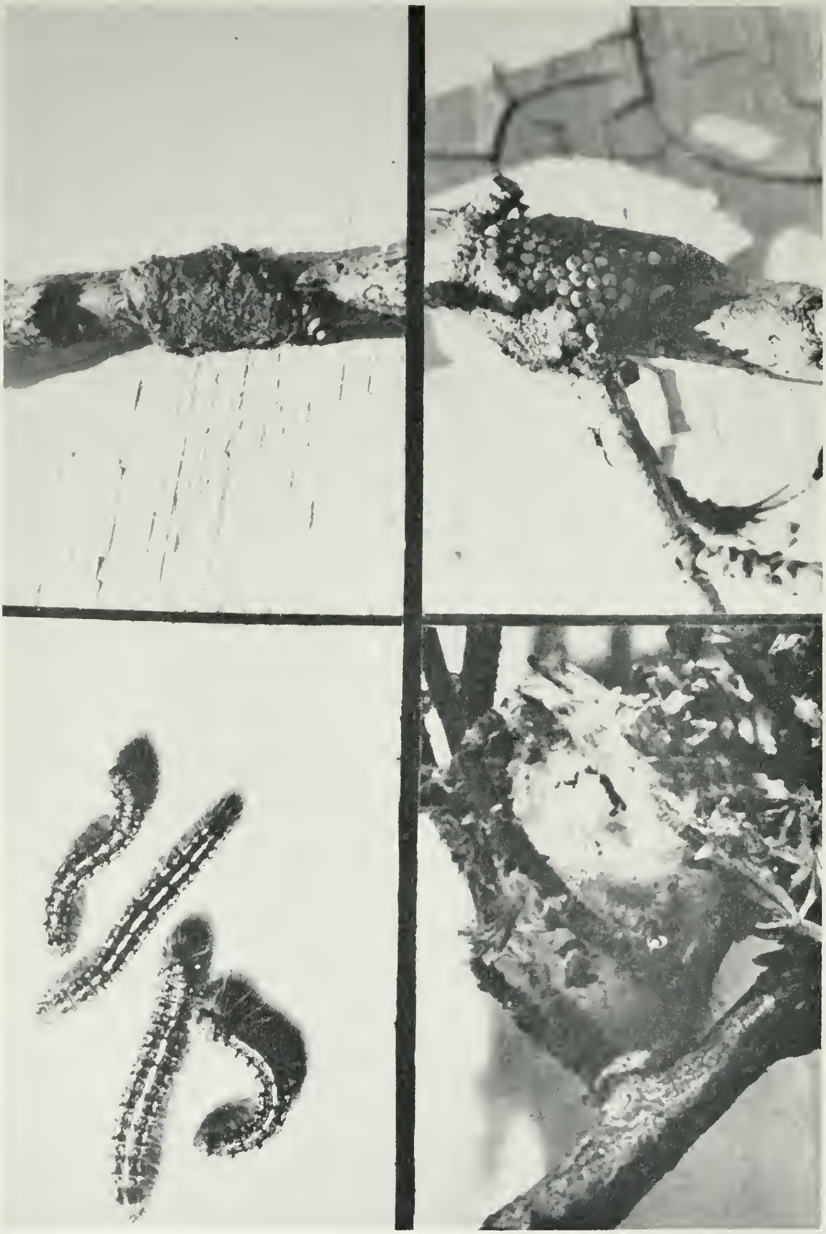

FIGURE 2. Immature stages of the Great Basin tent caterpillar. Upper left: egg mass on twig of bitterbrush (x2). Upper right: egg mass with portion of spumaline covering weathered away, exposing the eggs (x2). Lower left: fifth instar caterpillars (life size). Lower right: cocoon in leaves and twigs of bitterbrush (x2).

The approximate dates of the onset of pupation range from early to late June in the Mammoth Lakes area, mid-June to mid-July in the Modoc-Lassen area, and mid-July to mid-August in the Truckee Basin area (Figure 3). Adult flights follow the onset of pupation by about two weeks in all of the areas.

The adult males are reddish-brown and have a wing expanse of about $\frac{3}{4}$ to 1 inch; the females are cream-yellow with a wing expanse of 1 to $1\frac{1}{4}$ inch. Eggs are deposited by the adults shortly after they emerge from the cocoons.

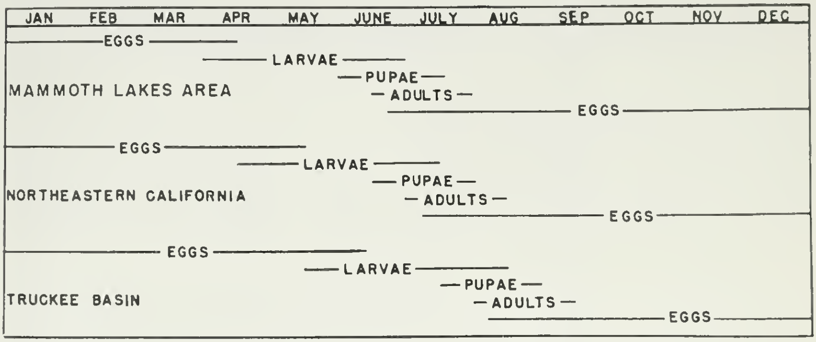

FIGURE 3. Approximate periods of occurrence of various stages of the Great Basin tent caterpillar in three areas of California. Indicated periods include possible seasonal variations and are longer than the duration of any stage in a given year.

Host Plants

The Great Basin tent caterpillar feeds on several plant species, as do most members of the genus *Malacosoma*. Essig (1926) listed ash, aspen, ceanothus, wild cherry, cottonwood, manzanita, oaks, wild plums, poplars, wild rose, willow, and orchard trees as its chief hosts. Keen (1952) listed bitterbrush, aspen, oak, poplar, willow, and "other shrubs and trees".

Plants on which *M. fragile* was observed feeding during the study reported here are listed in Table 1. It was noted frequently that the larvae wander to and feed on plant species on which the adults were not observed to oviposit. As an example, when an infestation occurs in a mixed stand of ceanothus, *Prunus* sp., and manzanita, the older larvae may be observed feeding on the manzanita as well as the ceanothus and *Prunus,* but the writer has not been able to find an egg mass or tent on manzanita at any time during this study. In Table 1, the listed plants are classified as primary or secondary hosts, depending on the presence or absence of an egg mass. Further observations will probably extend this list.

RELATION OF THE TENT CATERPILLAR TO BITTERBRUSH

Feeding Characteristics and Plant Response

Table 2 shows the phenological relationship of the various developmental stages of the insect to those of bitterbrush as observed in the Truckee Basin area during 1953. The larvae began feeding when the

TABLE 1

Host Plants of the Great Basin Tent Caterpillar Observed During This Study. Primary Host Class Indicates the Presence of an Egg Mass or Tent. Scientific Names From Jepson (1925).

Common name	Scientific name	Family	Locality of observation	Elevation in feet	Host class
Snowbrush	*Ceanothus cordulatus*	Rhamnaceae	Transition Zone, Sierra Nevada	4,000–7,500	Primary
Tobaccobrush	*C. velutinus*	Rhamnaceae	Viola, Lassen Co.	5,000–6,000	Primary
	Rhamnus sp.	Rhamnaceae	Truckee, Nevada Co.	5,600	Primary
Bitterbrush	*Purshia tridentata*	Rosaceae	Eastside	3,600–7,000	Primary
Wild rose	*Rosa* sp.	Rosaceae	Truckee, Nevada Co.	5,600	Primary
Bitter cherry	*Prunus emarginata*	Rosaceae	Blue Canyon, Placer Co.	4,500	Primary
Western choke cherry	*P. demissa*	Rosaceae	Truckee, Nevada Co.	5,600	Primary
Desert peach	*P. andersonii*	Rosaceae	Mono Co.	5,000	Primary
Gooseberry	*Ribes roezlii*	Saxifragaceae	Shaver Lake, Fresno Co.	5,000	Primary
Quaking aspen	*Populus tremuloides*	Salicaceae	Plumas Co.	6,000	Primary
Willow	*Salix* sp.	Salicaceae	Shaver Lake, Fresno Co.	5,000	Secondary
California hazel	*Corylus rostrata*	Corylaceae	Shaver Lake, Fresno Co.	5,000	Secondary
Elderberry	*Sambucus* sp.	Caprifoliaceae	Shaver Lake, Fresno Co.	5,000	Secondary

first plant leaves were about half grown, a stage that roughly coincides with the onset of flowering. Feeding continued throughout flowering and fruit maturation and through about three-quarters of the period of twig development. Thus, the feeding period of the insect encompasses the period of maximum physiological activity of the plant.

At high insect densities, the young caterpillars first destroy the leaves on a portion of the plant and later spread and defoliate the entire plant. When feeding is heavy, twig growth is prevented. The failure to produce new twigs may be the result of interference with the physiology of the plant or, more likely, the consumption of the succulent new growth by the insects as it develops. At the conclusion of feeding by the caterpillars, the plant may be devoid of photosynthetic tissue.

Plants that are completely defoliated, however, are capable of producing new leaves in the same season. In 1953, foliage was replaced almost completely by September on plants that had been completely defoliated in early August. Some of the leaves attained nearly full size. Twig growth started again, but the new twigs reached only ½ to 1 inch in length, compared with over 5 inches in length on foliated plants.

TABLE 2

Phenological Relationship of the Great Basin Tent Caterpillar and Bitterbrush as Observed at Truckee, Nevada County, California, 1953. (Adapted From Hormay, 1943).

Stage of plant development	Month						Stage of insect development
	May	June	July	Aug.	Sept.	Oct.	
Leaves growing	XXXX	XX					
	XXXX	XX					Eggs
Flowering	X	XXX					
		XXX	XXXX	XX			Larvae
Fruit maturing		X	XXXX	XX			
				XXX	X		Pupae
Twigs growing		X	XXXX	XXXX	XX		
				X	XXX		Adults flying

It is important to note that one of the values of bitterbrush as a browse species is that it provides green forage four to six weeks longer in the fall than most other desirable forage plants on the same site (Hormay, 1943). During this late grazing period, regrowth on defoliated plants is particularly succulent and attractive to grazing animals and such plants may be subject to further defoliation in the same season. In the case of the use of leader growth by deer in the fall, the animals may be forced to use the wood of the preceding season on plants the twig growth of which has been prevented or retarded by tent caterpillars.

Effects of Defoliation

The effects of the defoliation by the tent caterpillar on a bitterbrush range are the temporary one of removal of forage and the more permanent one of reduction of vigor of the stand. The loss caused by the removal of the forage is obvious since, under conditions of heavy infestations, the leaves and twigs of the plants may be completely destroyed over areas ranging from hundreds to thousands of acres. This loss occurs during the important grazing period of late spring or summer and extends for several weeks.

In considering the more permanent effect of the reduction of vigor of an individual plant or stand, it is necessary to regard the tent caterpillar as only one of many factors adversely affecting bitterbrush, rather than a single or unique agent. In view of the fact that both the plant and the insect are native species, it is obvious that *M. fragile* has been incapable of preventing the development of bitterbrush stands to their present distribution and abundance. During the period in which this development took place, however, bitterbrush was not sustaining grazing by livestock or deer to the extent that is experienced at the present time.

From this viewpoint, then, outbreaks of the tent caterpillar may be considered as tipping the balance toward decline of a bitterbrush stand; but the effects of a given infestation are conditioned or altered by the degree to which other adverse factors may have operated both before and after the infestation. Taking these variables into account, observations indicate that two successive defoliations may kill the weaker plants of the stand. In view of Hormay's statement (1943) that the maximum allowable cropping of current foliage of a single plant consistent with the maintenance of vigor of the plant is 60 percent, the damage by the caterpillar which may take 100 percent for two or more successive years is obvious.

Less obvious, but perhaps more important, than the outright killing of bitterbrush by the insect is the reduction in competitive vigor of the plant. Bitterbrush usually exists in intense competition with other range species. The most common of these, the sagebrushes (*Artemisia* spp.), have a marked competitive advantage in that they are not ordinarily heavily grazed by livestock or deer and never defoliated by the tent caterpillar. Under range use, bitterbrush seedling establishment may be seriously hampered by deer, sheep, and cattle grazing. Dasmann and Blaisdell (1954), for example, report that presently there is little replacement by reproduction of the dead and dying plants of the Lassen-Washoe range. In such a situation the reduction in competitive vigor or outright killing of bitterbrush by *M. fragile* is likely to be followed by the replacement of the plant with less desirable or even undesirable plant species.

The best available records of the effect of the Great Basin tent caterpillar on bitterbrush range are from U. S. Forest Service files (kindly made available by Mr. Fred P. Cronemiller). These records describe outbreaks in 1943, 1944, and 1945 in northeastern California. In 1943, tent caterpillar infestations were observed throughout a large area in Modoc County. The most concentrated of these infestations centered near Hackamore in the so-called "Badger Township," an area that

forms part of the winter range of the highly valued Devil's Garden interstate migratory deer herd. This range supports a large deer population in the fall and winter, and parts of it are grazed by cattle and sheep in the spring and summer. Under these conditions of heavy utilization of bitterbrush by grazing animals, tent caterpillar defoliation assumes its greatest importance.

In 1943, the tent caterpillar infested an estimated 50,000 acres near Hackamore. In 1944, about 70,000 acres, blanketing the 1943 area, were heavily infested, and on about one-half of this area the bitterbrush was completely defoliated. Much of the bitterbrush in the defoliated area was reported to have been killed. The rated grazing capacity of the infested range was estimated to be reduced by about 25 percent.

Mr. F. P. Cronemiller states (personal communication) that much of the bitterbrush killed by the 1943-1944 infestation has not been replaced to date.

The insect outbreak was terminated by natural factors in 1945. Dr. R. C. Hall, U. S. Forest Service, states (personal communication) that what we now know to be a virus-caused disease appeared to be the principle factor in the collapse of this insect population (Clark and Thompson, 1954; Clark, 1955).

HISTORY OF SEVERE OUTBREAKS

The history of severe outbreaks of *M. fragile* in the eastside portion of California is of interest in that it may shed light on important questions, answers to which may lead to an understanding and perhaps control of such outbreaks. We are concerned with the frequency with which destructive infestations may be anticipated, and it is of particular interest to know whether or not the insect populations in the three more-or-less isolated smaller areas are synchronized in their fluctuations.

The construction of such a history, however, is hampered by difficulties in defining the term outbreak and by the inadequacies of records of *M. fragile*.

The density of the population of the tent caterpillar on a given range may vary from nearly zero to the great numbers described in the preceding section. The designation of any given density as an ''outbreak'' is purely an arbitary matter. In addition, the increase from very low densities to very high and destructive densities is not always a uniform or uninterrupted progression. For example, two populations, one in Modoc County and the other in the Truckee Basin, have been observed for the past few years. In each case sufficient egg masses are laid in the fall and tents formed in the spring to create an impression of a heavy and increasing population. By the end of the larval developmental period, however, mortality caused by natural factors has been sufficient to prevent excessive damage to the plant and, apparently, to prevent noticeable increases in population. As a result, these infestations appear to have remained fairly static and nondestructive.

In the description of the history which follows, infestations which were destructive to the plant over fairly large areas and which stimulated concern on the part of range management officials and others are called outbreaks. The information that follows has been

collected from scattered Forest Service records and correspondence, a few published communications, and the recollections of range management officials, western forest entomologists, and stockmen. The source of the information is given with the description of each outbreak.

Van Dyke (1914, 1928) reported heavy populations from Truckee northward to the Klamath Indian Reservation in southern Oregon in 1914, 1921, and 1928. These reports may be qualified in that Great Basin tent caterpillar infestations ordinarily remain at very high densities for two or three years rather than one, as indicated.

Destructive populations in the Truckee area again occurred in 1938 or 1939 and 1940 (Mr. A. Fausett). In 1949 and 1950, small colonies reappeared throughout the area. This infestation has persisted with a more-or-less static population to date.

The 1943-1945 infestation near Hackamore has been described in a preceding section.

Records of the former Forest Insect Laboratory, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, show an outbreak in the Mammoth Lakes area in 1937 and 1938. According to Mr. A. Fausett of the Inyo National Forest, heavy populations were present again in this area in 1943 and 1944. While apparently not as heavy as the 1937-1938 outbreak, this infestation covered a wide area and completely defoliated blocks as large as two or three hundred acres. Since 1945, scattered and light populations have been found in most years, but damage has been of little consequence.

The periods of occurrence of high densities of the Great Basin tent caterpillar are summarized in Figure 4. As pointed out earlier, conclusions drawn from this information must be qualified by the subjective definitions of outbreak and the initial year of outbreak, and the possibility that different observers have described different conditions with the same terms.

The data suggest, however, that the insect does not follow a seven-year cycle, as has been suggested (Van Dyke, 1928). Thus, Mr. R. W. Beeson, Supervisor of the Modoc National Forest from 1935 to 1940, reports that no heavy infestations occurred in Modoc County during the 1930's. It can also be definitely stated that there have been no destructive outbreaks in this area from 1945 through 1955. It is further suggested that there is not sufficient regularity in population fluctuations to predict their occurrences very far in advance. Preliminary attempts do indicate that a system of fall egg mass sampling could be developed to give an accurate prediction of the maximum possible infestation in the following spring.

The question of synchronous outbreaks requires clarification by more adequate records. Such evidence as is available (Figure 4) does not suggest concurrent high-density populations in the three areas studied. Figure 4 shows a period of 2 or 3 years between the high populations in the Mammoth Lakes and Truckee Basin areas in the late 1930's and in northeastern California in 1943. However, the reliability of these records is not sufficient, as noted above, to permit definite conclusions.

SUMMARY

The Great Basin tent caterpillar (*Malacosoma fragile*) is a serious pest of bitterbrush (*Purshia tridentata*). Defoliation by this insect is one of several factors which may contribute to the decline of bitterbrush ranges. *M. fragile* is of particular importance in three areas in the eastside portion of California: Mammoth Lakes; Truckee Basin; and Modoc and Lassen counties.

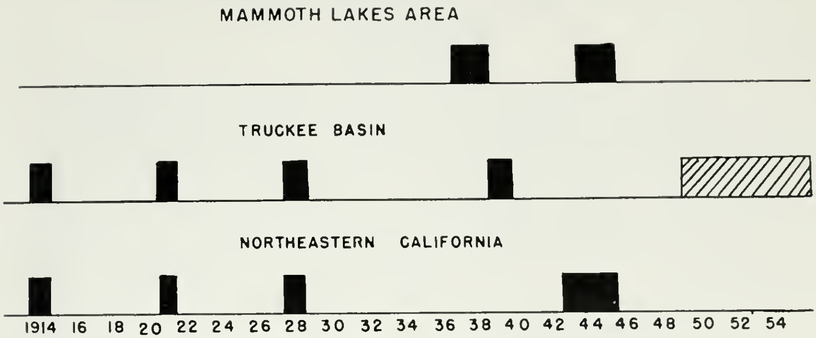

FIGURE 4. Occurrences of outbreaks of the Great Basin tent caterpillar in three areas of California. Cross-hatching indicates a population of lower density than the insect frequently attains. No information available prior to 1937 for the Mammoth Lakes area.

The life cycle is similar to that of other members of the genus *Malacosoma*. The insect overwinters as the first instar larva within the egg. Hatching occurs after the development of new leaves on the host plant, and development of the larvae requires about two months. Pupation, adult flight, and oviposition occur in early to late summer, depending on the latitude, altitude, and seasonal weather.

M. fragile is a fairly omnivorous feeder. Oviposition on 10 plant species in 4 families was observed during this study. In California, the insect attains very high densities on bitterbrush and on *Ceanothus* spp.

The feeding period of the caterpillars encompasses the period of maximum physiological activity of the plant. Heavily infested plants may be devoid of leaves and new leader growth at the conclusion of caterpillar feeding in the late spring or summer. Such plants may produce new foliage in the same season but may be further weakened by grazing animals in the fall. In areas in which leader growth has been prevented or destroyed by tent caterpillars, deer may be forced to take the wood of preceding seasons. It appears that two consecutive defoliations by tent caterpillars may kill the weaker plants in a stand.

Destructive caterpillar populations have occurred periodically in important grazing areas in California. One such population for which adequate records are available spread over 70,000 acres of grazing land and completely defoliated bitterbrush on about one-half of this area. The rated carrying capacity of the infested range was reduced by about 25 percent.

In addition to the killing of bitterbrush, repeated tent caterpillar defoliation may reduce the vigor of surviving plants. The reduction in competitive ability may be followed by the replacement of bitterbrush by less desirable or even undesirable range species.

A tentative construction of the history of large outbreaks of *M. fragile* in California indicates that such outbreaks do not follow a well-defined cycle. Whether or not they are synchronized in the three areas of importance requires clarification by more adequate records.

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AGE COMPOSITION OF THE SOUTHERN CALIFORNIA CATCH OF PACIFIC MACKEREL FOR THE 1954-55 SEASON[1]

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This is the fifth report on the age composition of the Pacific mackerel (*Pneumatophorus diego*) catch. The methods of sampling, age determination, and estimation of numbers of fish are the same as those used in the previous reports, which covered the period 1939-40 through 1953-54. The catch of 26,719,000 pounds during 1954-55, though nearly three times greater than the 1953-54 landings, was still poorer than in any season from 1933-34 through 1951-52 (Table 1). This 20-year interval marks the time since modern canning methods pushed the Pacific mackerel into prominence as a commercial species.

TABLE 1

Pacific Mackerel Landings by Seasons

Season	Pounds of fish	Season	Pounds of fish
1926-27	3,593,962	1940-41	107,553,929
1927-28	6,455,033	1941-42	71,754,709
1928-29	39,405,114	1942-43	48,220,187
1929-30	56,694,637	1943-44	77,853,106
1930-31	12,805,751	1944-45	80,785,356
1931-32	15,152,465	1945-46	52,002,734
1932-33	10,850,403	1946-47	58,896,372
1933-34	72,873,851	1947-48	39,627,373
1934-35	113,464,209	1948-49	38,202,903
1935-36	146,387,327	1949-50	50,061,684
1936-37	100,745,270	1950-51	33,890,004
1937-38	70,445,621	1951-52	31,901,919
1938-39	76,064,647	1952-53	18,761,833
1939-40	99,960,747	1953-54	7,612,679
		1954-55	26,719,000

Lengths of the 811 mackerel from which otoliths were read during the 1954-55 season are presented in Table 2. These fish ranged in age from zero through seven. None had hatched prior to 1947, and not a single fish of the 1949 year class (age group five) was encountered. More than three-fourths of the fish that were aged were from the 1953 year class, 12 to 24 months old.

Of the total season's take—44,811,000 fish (Table 3)—over 40 million or 89 percent were contributed by the 1953 year class. None of these one year olds had spawned prior to capture. Only during the 1948-49

[1] Submitted for publication October, 1955.

TABLE 2

Fork Length of Pacific Mackerel in Quarter Centimeters at Each Age for the 1954-55 Season, Based on Otoliths Read

¼ cm.	Age group							
	O	I	II	III	IV	V	VI	VII
70	--	--	--	--	--	--	--	--
71	--	--	--	--	--	--	--	--
72	--	--	--	--	--	--	--	--
73	2	--	--	--	--	--	--	--
74	--	--	--	--	--	--	--	--
75	--	--	--	--	--	--	--	--
76	--	--	--	--	--	--	--	--
77	2	--	--	--	--	--	--	--
78	--	--	--	--	--	--	--	--
79	--	--	--	--	--	--	--	--
80	1	--	--	--	--	--	--	--
81	1	--	--	--	--	--	--	--
82	--	--	--	--	--	--	--	--
83	--	--	--	--	--	--	--	--
84	2	--	--	--	--	--	--	--
85	--	--	--	--	--	--	--	--
86	--	--	--	--	--	--	--	--
87	--	--	--	--	--	--	--	--
88	1	--	--	--	--	--	--	--
89	--	--	--	--	--	--	--	--
90	--	--	--	--	--	--	--	--
91	--	--	--	--	--	--	--	--
92	--	--	--	--	--	--	--	--
93	--	3	--	--	--	--	--	--
94	--	2	--	--	--	--	--	--
95	--	--	--	--	--	--	--	--
96	--	1	--	--	--	--	--	--
97	--	3	--	--	--	--	--	--
98	--	13	--	--	--	--	--	--
99	--	18	--	--	--	--	--	--
100	--	25	--	--	--	--	--	--
101	--	12	--	--	--	--	--	--
102	--	19	--	--	--	--	--	--
103	--	16	--	--	--	--	--	--
104	--	26	--	--	--	--	--	--
105	--	27	--	--	--	--	--	--
106	--	22	--	--	--	--	--	--
107	--	20	--	--	--	--	--	--
108	--	21	--	--	--	--	--	--
109	--	34	--	--	--	--	--	--
110	--	41	--	--	--	--	--	--
111	--	27	--	--	--	--	--	--
112	--	23	--	--	--	--	--	--
113	--	28	--	--	--	--	--	--
114	--	36	--	--	--	--	--	--
115	--	23	1	--	--	--	--	--
116	--	37	1	--	--	--	--	--
117	--	28	2	--	--	--	--	--
118	--	26	4	--	--	--	--	--
119	--	15	2	--	--	--	--	--
120	--	11	8	--	--	--	--	--

TABLE 2—Continued

Fork Length of Pacific Mackerel in Quarter Centimeters at Each Age for the 1954-55 Season, Based on Otoliths Read

¼ cm.	Age group							
	O	I	II	III	IV	V	VI	VII
121		18	11					
122		17	19					
123		12	4					
124		5	7					
125		1	11					
126		3	11	1				
127		3	12					
128			5	1				
129			13					
130		1	3	2				
131			8		1			
132			3	2				
133			5					
134				3				
135				1				
136			2	5	1			
137				5	3			
138				3	1			
139				1				
140				1	1			
141					1			
142					1			
143					1			
144					1			
145					1			
146					1			
147					1		1	
148					1		1	
149					1			
150							1	
151								
152							1	
153								
154								
155								
156								
157								
158								1
159								
160								
161								1
Totals	9	620	132	28	16	0	4	2

season, when the 1947 hatch made up more than 90 percent of the take, has the Pacific mackerel fishery showed such a dependency upon year-old fish.

TABLE 3

Calculated Number of Pacific Mackerel Landed for Age Groups 0 Through VI+ for the 1954-55 Season

	Age group							
	O	I	II	III	IV	V	VI+	Totals
Year class	1954	1953	1952	1951	1950	1949	---	---
Number of fish	564,000	40,036,000	3,893,000	208,000	71,000	0	39,000	44,811,000
Percentage of fish	1.3	89.3	8.7	0.4	0.2	0.0	0.1	100.0

The unrestricted removal of such quantities of immature fish must spell the doom of this natural resource. More thought should be given to the future by those engaged in the prosecution of this fishery. Only seven-tenths of 1 percent of the 44.8 million fish caught during the 1954-55 season were older than 36 months (Table 3).

The 1949, 1950, and 1951 year classes, which yielded 1,219,000 fish weighing 1,399,000 pounds during the 1953-54 season (Tables 4 and 5), were able to produce only 279,000 fish weighing 324,000 pounds during 1954-55. Based upon past trends (Table 4) it seems probable that neither the 1953 nor 1954 year class will contribute as many fish to the 1955-56 catch as it did during the season just ended. From these tables it is not difficult to predict that, unless a superior hatch occurs in either 1955 or 1956, it will be impossible for the fishery to yield more than five million pounds two seasons hence (1956-57). A superior hatch during either of these two years is only remotely possible when one considers the meager spawning stock from which these must result.

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TABLE 4

Number of Fish Landed by Year Class at Each Age Group From 0 Through V, 1939-40 Through 1954-55

Year class	Age group						Totals
	0	I	II	III	IV	V	
1934	-----	-----	-----	-----	-----	5,340,000	-----
1935	-----	-----	-----	-----	10,570,000	1,443,000	-----
1936	-----	-----	-----	35,130,000	13,551,000	970,000	-----
1937	-----	-----	26,540,000	25,261,000	5,121,000	822,000	-----
1938	-----	25,200,000	69,322,000	25,661,000	5,271,000	1,082,000	*126,536,000
1939	2,960,000	20,793,000	26,454,000	12,698,000	7,133,000	1,616,000	71,654,000
1940	2,313,000	12,507,000	9,204,000	10,156,000	7,712,000	3,328,000	45,220,000
1941	398,000	29,376,000	54,106,000	33,905,000	10,312,000	2,294,000	130,391,000
1942	0	12,462,000	19,047,000	10,259,000	4,661,000	2,019,000	48,448,000
1943	836,000	16,556,000	10,327,000	11,872,000	5,087,000	429,000	45,107,000
1944	0	14,302,000	25,823,000	10,943,000	1,105,000	584,000	52,757,000
1945	556,000	9,330,000	7,980,000	756,000	688,000	72,000	19,382,000
1946	560,000	1,377,000	3,175,000	4,279,000	937,000	218,000	10,546,000
1947	7,181,000	63,330,000	49,255,000	15,826,000	11,127,000	2,756,000	149,475,000
1948	1,061,000	21,818,000	19,228,000	13,871,000	9,484,000	367,000	65,829,000
1949	136,000	3,854,000	4,428,000	1,286,000	161,000	0	9,865,000
1950	6,000	1,583,000	521,000	583,000	71,000	-----	2,764,000
1951	769,000	46,000	475,000	208,000	-----	-----	1,498,000
1952	86,000	676,000	3,893,000	-----	-----	-----	4,655,000
1953	12,237,000	40,036,000	-----	-----	-----	-----	-----
1954	564,000	-----	-----	-----	-----	-----	-----

* No information available on the 0 age group of the 1938 year class.

TABLE 5

Pounds of Fish Landed by Year Class at Each Age Group 0 Through V, 1939-40 Through 1954-55

Year class	Age group						Totals
	0	I	II	III	IV	V	
1934						6,851,000	
1935					12,141,000	1,885,000	
1936				31,946,000	14,592,000	1,414,000	
1937			19,306,000	22,163,000	7,015,000	1,178,000	
1938		11,578,000	49,762,000	27,249,000	6,651,000	1,499,000	*96,739,000
1939	961,000	11,609,000	21,747,000	12,898,000	9,058,000	2,334,000	58,607,000
1940	853,000	7,564,000	7,809,000	10,743,000	10,139,000	4,809,000	41,917,000
1941	116,000	15,085,000	40,066,000	36,527,000	13,595,000	3,236,000	108,625,000
1942	0	7,912,000	16,208,000	11,453,000	6,225,000	2,863,000	44,661,000
1943	274,000	9,991,000	9,221,000	12,786,000	6,718,000	638,000	39,628,000
1944	0	7,296,000	22,530,000	13,035,000	1,484,000	852,000	45,197,000
1945	158,000	5,627,000	7,601,000	867,000	899,000	100,000	15,252,000
1946	129,000	1,015,000	2,365,000	4,070,000	1,078,000	290,000	8,947,000
1947	1,477,000	29,643,000	32,320,000	14,692,000	12,819,000	4,058,000	95,009,000
1948	248,000	8,612,000	13,591,000	13,327,000	12,583,000	637,000	48,998,000
1949	47,000	2,155,000	3,547,000	1,509,000	229,000	0	7,187,000
1950	1,000	802,000	474,000	687,000	90,000		2,054,000
1951	252,000	34,000	483,000	234,000			1,003,000
1952	33,000	463,000	3,063,000				3,559,000
1953	4,358,000	23,175,000					
1954	94,000						

* No information available on the 0 age group of the 1938 year class.

EARLY LARVAE OF FOUR SPECIES OF ROCKFISH, *SEBASTODES*[1]

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INTRODUCTION

This paper presents some descriptive information regarding the early larvae of four species of *Sebastodes* in the hope that it will facilitate the work of various individuals and organizations engaged in plankton studies and surveys. The chilipepper, *S. goodei*, and the bocaccio *S. paucispinis*, are commercially important species in California (Roedel, 1948). To my knowledge, the popeye rockfish, *S. saxicola*, and the slim rockfish, *S. jordani*, are not objects of a fishery, but the latter species apparently occurs in prodigious numbers and is probably an important deep-water forage fish.[3]

There are about 50 species of *Sebastodes* along the California coast and present knowledge of their biology indicates that they are all ovoviviparous. Unlike the ovoviviparous sharks and viviparous embiotocids, which produce only a few large, well-developed young at a time, the *Sebastodes* produce thousands of small, relatively undeveloped larvae. When embryonic development is complete, the females shed the eggs and the resultant exposure to sea water acts as a hatching stimulus and also activates the larvae.

The descriptions offered in this paper were derived from several hundred larvae artificially stripped from one adult of each of the four species. *Sebastodes* is an extremely difficult genus and offspring from only one female were used in order to insure positive identification. These descriptions are, however, consistent with observations I have made on larvae representing several scores of females of these species.

The larvae described in this paper were taken from fish caught by Captain F. M. Rhodes of the dragger MIDNIGHT SUN. The catch was made off Monterey, California, at a depth of about 100 fathoms, December 15, 1953. The larvae were stripped into jars of sea water within a few minutes after the fish were taken aboard the boat. The ovarian phase of development was apparently complete and the larvae began to swim vigorously within moments of the time they were placed in sea water.

The jars containing the larvae were taken to the laboratory and the larvae were transferred to stoneware crocks of sea water. The water was kept in gentle, helical motion by means of stirring discs. Temperatures ranged from 11 to 14.5 degrees C. during the period of observa-

[1] Submitted for publication October, 1955.
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[3] The common names used are those given by Carl L. Hubbs and W. I. Follett in their unpublished *Manuscript List of the Fishes of California*.

tion. Some larvae of each of the four species fed on nauplii of *Artemia,* but none survived transition from the yolk-sac stage. The maximum times that any specimens of the four species survived were as follows: *S. goodei,* 12 days; *S. saxicola,* nine days; *S. paucispinis,* eight days; *S. jordani,* seven days.

GENERAL DESCRIPTION

Figure 1 shows the dorsal aspects of the head and trunk of *Sebastodes goodei* and *Oligocottus snyderi.* It may be seen that the head of *S. goodei* tapers anteriorly at a relatively acute angle. An acutely tapered snout (as seen in dorsal view) is common to all four species of *Sebastodes* discussed in this paper and contrasts sharply with the condition I have observed in larvae of several other genera. *Oligocottus snyderi* is arbitrarily used as an example of the many cottids, hexagrammids, and other scleropareid larvae which have a general appearance similar to that of *Sebastodes* larvae and occur in the same general range.

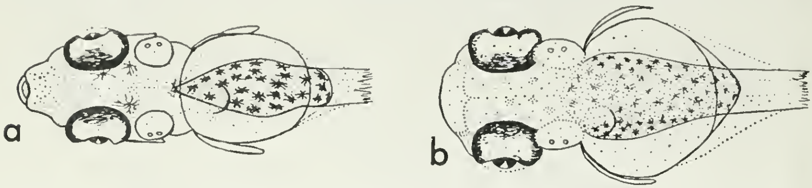

FIGURE 1. Dorsal view of the head and trunk of: (a) *Sebastodes goodei* and (b) *Oligocottus snyderi.* Note the difference in outlines of the heads.

The optic lobes are large in *Sebastodes* (Fig. 2), giving the head a high profile when viewed in lateral aspect.

About 25 to 27 myomeres may be seen in each of these four species. This agrees closely with the numbers of vertebrae (26 or 27) found by Clothier (1950) among adults of 10 species of *Sebastodes* that he examined.

The dorsal finfold has a small discoidal indentation on each side, above the approximate center of the trunk (Fig. 2). A fine line extends from each member of this pair of indentations to a nearby myocomma. These structures were found in all of the four species. I have not observed them in larvae of other genera, nor do I have any knowledge of their function.

MELANOPHORES

The distribution of melanophores in the newly-hatched larvae are shown in Figure 2. Table 1 brings out similarities and contrasts in the distribution of melanophores among the four species.

During the yolk-sac stage the pectoral fins of *S. goodei* become entirely black and those of *S. paucispinis* develop black margins. The pectoral fins of the other two species remain unpigmented during this period.

A few melanophores are added to the region over the head in *S. goodei* and a few appear in this region in *S. paucispinis* during the yolk-sac stage. During this period the top of the head remains unpigmented in the other two species.

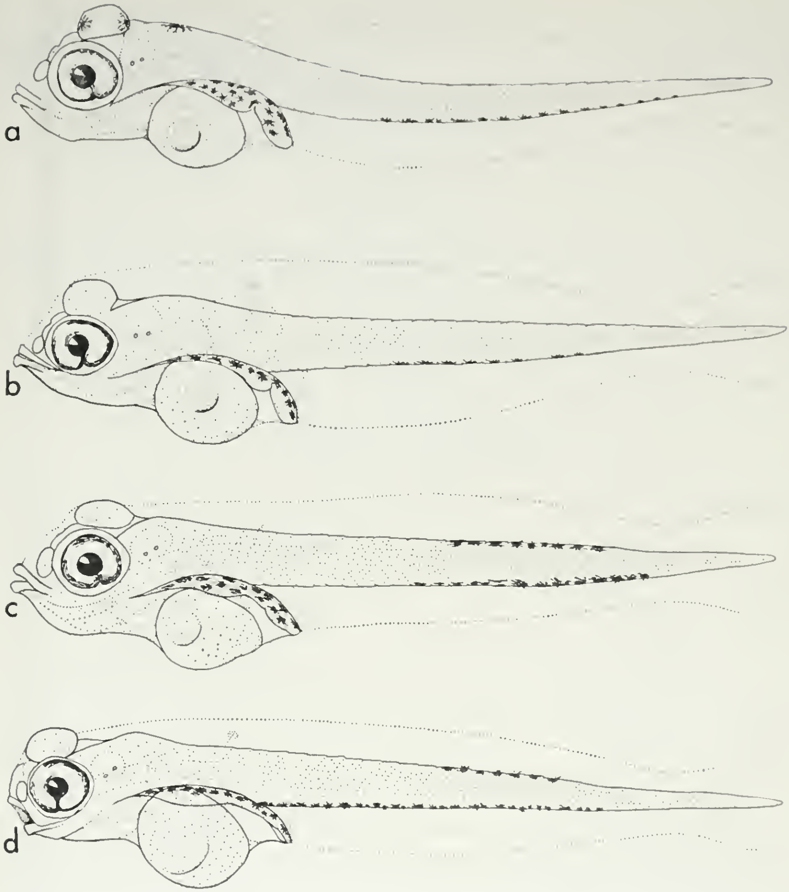

FIGURE 2. Newly hatched larvae of four species of *Sebastodes:* (a) *S. goodei,* 5.7 mm., (b) *S. paucispinis,* 6.0 mm., (c) *S. jordani,* 6.8 mm., and (d) *S. saxicola,* 4.3 mm. (The drawings and standard lengths are from living specimens.)

TABLE 1

Distribution of Melanophores in the Various Body Regions at Time of Hatching

Species	Over body cavity	Series along ventral profile of the tail	Series along dorsal profile of the tail	Top of head
S. goodei	Heavy group	Along middle two-thirds	None	2 or 3
S. paucispinis	Heavy group	Along middle one-third	None	None
S. jordani	Heavy group	Along middle one-half	Along middle one-third	None
S. saxicola	Heavy group	Along anterior two-thirds (continuous with the group over the body cavity)	Along middle one-fourth	None

CAROTENOIDS

The yolk colors observed were consistent within each species and are as follows: *S. goodei*, dull green; *S. paucispinis*, dark yellow; *S. jordani*, yellow; *S. saxicola*, pale greenish-yellow.

The oil globule was more intensely colored than the granular yolk in all species. The specimens faded badly in ordinary formalin preservation.

MEASUREMENTS

Proportions derived from the measurements given in Table 2 show such interspecific similarities that it seems improbable that they will aid materially in specific identification. These measurements should, however, help to distinguish between *Sebastodes* and other genera.

TABLE 2

Mean Measurements Taken at Hatching (h) on Twenty Specimens and Five Days After Hatching (5) on Ten Specimens

Measurements, in Millimeters, Made With Ocular Micrometer Graduated to 0.02 mm.

Species	Standard length		Diameter of eye		Tip of snout to anus		Tip of snout to posterior edge of otic capsule		Depth in the vertical of the heart	
	(h)	(5)	(h)	(5)	(h)	(5)	(h)	(5)	(h)	(5)
S. goodei	4.12	5.01	0.31	0.42	1.47	1.84	0.59	0.85	0.64	0.87
S. paucispinis	4.65	4.74	0.39	0.39	1.75	1.68	0.87	0.95	0.83	0.70
S. jordani	5.40	5.90	0.42	0.46	1.98	2.01	0.97	1.04	0.83	0.81
S. saxicola	3.72	4.41	0.30	0.31	1.48	1.57	0.56	0.73	0.58	0.62

Comparative measurements of pectoral fins were not considered. Growth of these fins was extremely rapid immediately after hatching and in all four species they quickly attained a length of about 0.7 to 0.8 mm. There is no significance in the differences in size of the pectorals among the larvae figured.

The diameter of the oil globule of *S. saxicola* is about 0.3 mm. at hatching. In the other three species it is only about 0.2 mm. Since size of the oil globule diminishes rapidly and steadily, it is probably of little value in identification.

REMARKS ON IDENTIFICATION

The early larvae of the species of *Sebastodes* described above have a number of common characters that should serve to distinguish them from other genera. They can be distinguished from comparable stages of the closely related oviparous *Scorpaena guttata* on the basis of size alone. Orton (1955) gives the total length of living, newly-hatched individuals of that species as being only about 1.9 to 2.0 mm. Orton also states that only 24 somites can be seen in *Scorpaena* and the illustrations she presents show much less pigmentation of the tail than is found in the *Sebastodes* larvae discussed in this paper.

The differences in melanophore patterns should be helpful in specific identification. However, specific identification of the larvae will probably be extremely difficult because of the large number of close relatives in this genus.

ACKNOWLEDGMENTS

I wish to thank Mr. J. B. Phillips of the California Department of Fish and Game for identifying the adults from which the larvae discussed in this paper were taken. I also wish to thank Dr. E. H. Ahlstrom of the U. S. Fish and Wildlife Service for helpful suggestions regarding presentation of the descriptions.

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RETIREMENT

W. L. SCOFIELD

W. L. Scofield, former director of the California State Fisheries Laboratory, retired from the California Department of Fish and Game on December 31, 1955, winding up a career with the State of nearly 37 years.

Scofield was graduated from Stanford University in 1911, receiving a bachelor's degree in botany. In 1913 he received a master's degree from the Yale University School of Forestry.

The veteran worker was employed by the United States Forest Service during the summers of 1911 and 1912 and worked for the agency uninterruptedly from 1913 to 1917.

Scofield is a veteran of World War I and during that time was placed on detached service in various forestry assignments in France.

His career with the State began in April, 1919. He first worked on salmon investigations at Monterey until 1920, when he transferred to sardine studies.

Scofield was appointed director of the California State Fisheries Laboratory at Terminal Island in March, 1925. In January, 1942, he was made public relations coordinator and liaison representative between the Marine Fisheries Branch and the other branches of the Department of Fish and Game.

He is the author of bulletins on various types of commercial gear. One concerning trolling gear is awaiting publication. He has also compiled a comprehensive historical account of all of California's fishing ports.

Scofield's exceptional knowledge of the history of California's fishing industry and of early regulations aided in building a strong foundation for the Marine Fisheries Branch.

One of his favorite projects was the annual Pismo clam census, which he started and worked on about two weeks each year. He completed his final survey the last week in November.—*Richard S. Croker, Chief, Marine Fisheries Branch, California Department of Fish and Game.*

REVIEWS

The Edge of the Sea

By Rachel Carson; Houghton Mifflin Company, Boston, 1955; viii + 276 p., illustrated by Bob Hines. $3.95.

Rachel Carson, who won worldwide fame as an author with publication of "The Sea Around Us" in 1951, now has chosen one particular area of that "sea" for a more critical study. "The Edge of the Sea", as the title implies, presents that part of the sea which meets the shore, where complex relationships between organisms and their environment abound. The concepts involved in describing the forces of the sea and how they mold the lives of the intertidal flora and fauna are written in the Carson style. That is, scientific facts are backed up by a vast store of experience and presented in a popular, readable fashion.

The reader is first introduced to a few of the author's personal experiences at the seashore and to some generalizations relative to the physical influences of the environment. The three chapters which form the foundation of the book are entitled: (1) The Rocky Shores, (2) The Rim of Sand, and (3) The Coral Coast. Because of its configuration and geologic history, the eastern coast of the United States was chosen as the representative example of these typical environments. Familiarity with the area undoubtedly influenced that choice.

Excellent life-like pencil drawings are liberally distributed throughout the book. These, plus the general discussion in the appendix of each animal phylum, aid greatly in the understanding of marine animals.

For those who read and enjoyed "The Sea Around Us" here is another opportunity to gain scientific information in popular form. For those not acquainted with Miss Carson's writings "The Edge of the Sea" is an introduction to fine reading on a most interesting subject.—*William L. Craig, California Department of Fish and Game.*

Fishes of Japan

By Yaichiro Okada; Maruzen Co., Ltd., Tokyo, 1955; 434 + 28 p., 391 figs. $10.

The species illustrated and described are typical representatives of the more than 1,000 known to inhabit the waters in and around Japan. Such a comprehensive volume (in English) has been long needed by workers throughout the world. For each of the 391 fishes figured, there is a brief description, and in some instances, natural history statements under the heading of "Habits". From these, one can find out little or much on the distribution, ecology, life history, method of capture, and utilization of the species in question. Less frequently is one informed of the differences between the fish at hand and a closely related form.

Though there are no keys to assist in classification, the excellent figures, many original, suffice for identification. For the individual who prefers to locate a species by viewing pictures this book will prove a veritable treasure trove.

Typographical and other errors are not glaring. Those that do crop up have resulted from an unfamiliarity with the English language rather than careless preparation. Occasional peculiarities of expression neither confuse the user nor detract from the readability of the book.

Of particular interest are the various comments on palatability. Some of the numerous statements that take one through a complete cycle of gastronomical experiences are: "the flesh is tasty", "it is a food fish", "the flesh may be regarded as a food", "it is a food fish of lower grade", "inferior to the preceding species", "the flesh is sometimes eaten but usually utilized as a fertilizer", "not regarded as a food fish", and "its flesh is not tasty". One species is "regarded as an important food for impregnated women" and two fishes highly prized by Californians (bonito and starry flounder) are unflavorably described by the phrases: "the soft flesh is not tasty" and "the flesh is not tasty".

The book is well indexed: 12 pages of scientific names and 16 of Japanese and English common names.—*John E. Fitch, California Department of Fish and Game.*

Wild America

By Roger Tory Peterson and James Fisher; Houghton Mifflin Company, Boston, 1955; xii + 434 p., illustrated by Roger Tory Peterson. $5.

Mr. Peterson, eminent American naturalist, conducts James Fisher, his English counterpart, on a 30,000 mile tour of the continent. Starting at Newfoundland, their journey takes them down the Atlantic seaboard to Florida, across the Gulf country and into Mexico, across the American southwest, up the west coast to Washington, and thence by air to western Alaska and the Pribilof Islands.

Their journey was planned so as to hit the high spots of scenic attractions. Although the authors touch on all phases of nature, their chief interest is in the bird life. Over 600 species of birds were recorded in their notebooks during the trip, which encompassed a hundred days of traveling time.

An unusual feature of the book is that the authors take turns in writing the text. Mr. Fisher's comments are especially interesting in that he gives a Britisher's viewpoint of our American scene. This was Mr. Fisher's first trip to the continent.

The book is well written and will interest all people who enjoy travel books written from the naturalist's point of view.

The text is profusely illustrated with excellent black and white sketch drawings which makes the book an attractive addition to one's library.—*C. M. Ferrel, California Department of Fish and Game.*

California Grizzly

By Tracy I. Storer and Lloyd P. Tevis, Jr.; University of California Press, Berkeley, 1955; vii + 335 p., illus. $7.50.

This book describes the grizzly bear in California and the manner of life it had in contact with first the Indians, then the Spanish, and finally the Americans. As the grizzly has been extinct in California since the 1920's, this account is of necessity historical, drawn mainly from the written and published record. The authors have searched newspaper accounts, books on California, and private diaries for scraps of information on this animal and have brought together this information and placed it in continuity.

The grizzly has always been an object of great interest, even to those with only a meager interest in less spectacular animals. To Californians, this animal is of special interest since we use it as an emblem on our State Flag and Seal and it has been designated the State animal.

Although some of the accounts are rather dull and repetitious, other parts are exciting—such as the descriptions of roping grizzlies and of the bear and bull fights. There is a chapter on grizzly hunting in California and one on Grizzly Adams, California's most famous grizzly hunter.

Before the coming of the white man to California, the grizzly, rather than man, dominated the scene and was at the top of the food chain. The Indians with their inadequate weapons were afraid of grizzlies and many tribes were reluctant to try to trap or hunt them. This fear of bears was used by persons in different tribes to plunder or kill Indians of other tribes, or those of their own tribe against whom they had a grudge. These Indians, who dressed themselves in bearskin suits, gave rise to the belief that some men were able to change into grizzlies and back to Indians again as the mood pleased them, in much the fashion of the werewolf of central Europe.

Some tribes, however, tried to kill grizzlies by shooting at them from trees or pits. Some trapped them with deadfalls.

With the coming of the Spaniards, grizzlies were pursued for sport. Bear roping became a popular but dangerous sport.

These bears after being roped were often used in bear and bull fights, which were usually held on feast days.

With the coming of the Spaniards and the cattle industry, the grizzlies reached their peak population, since the cattle formed an abundant food supply. With the coming of the miners, grizzlies were slaughtered for food and it wasn't long until these great beasts were extinct in California.

This attractive book should be of interest to the general public as well as to naturalists and professional zoologists.—*Wallace Macgregor, California Department of Fish and Game.*

The Beast That Walks Like a Man

By Harold McCracken; Hanover House, Garden City, N. Y., 1955; 319 p.; illus. $4.50.

This book is an interesting and very readable account of the grizzly bear *(Ursus horribilis)*, an animal in which the author has maintained a life-long interest.

The grizzly has been on the North American continent for a long time—as long ago as the Pleistocene period, which goes back about 1,250,000 years. The remains of a prehistoric grizzly found in the Rancho LaBrea tar pits are reported to belong to one of the largest and most powerful known carnivorous animals of Pleistocene times. Although of less extraordinary dimensions than their prehistoric relatives, the grizzlies found on this continent by the Indians and later by the white man made themselves feared and respected. They played an important role in Indian legends, of which several are given in McCracken's book, along with accounts of Indian lore about this interesting animal.

With the advent of the early explorers and later the mountain men, the encounters with the fearless and pugnacious grizzly made tales worth telling and many of these are given, together with historic detail of this romantic period. Of special interest to Californians is the chapter on bear and bull fights, a feature of early Californian life that persisted to the 1860's. The exploits of "Grizzly" Adams, who captured, tamed, and trained several of these huge bears to help him hunt their relatives, and who later lived with them in the basement of a house on Clay Street, San Francisco, make up part of the accounts of this pioneer period.

With the coming of livestock to the west, a war of extermination was declared on the grizzly bear and the slaughter was intensified with the settlement of the land by ranchers. It was thought that the only good grizzly was a dead grizzly. Many varieties of the grizzly, including seven listed for California, have been exterminated.

Although the author estimates that there were at least 100,000 of these big bears in the United States in pioneer times, a total population of only 850 to 875 appears to have been left in 1953. Of these, about 300 are within Yellowstone and Glacier National Parks. The State of Montana reports a grizzly population of 437 plus 120 inside Glacier National Park. Wyoming claims 62, Idaho reports 67, and Colorado may have 32 of these animals left.

Although the grizzly is now walking the borderline of total extermination within this county, only Idaho gives it year-long protection. In that state there has been no open season since 1946, although animals may be killed if found molesting livestock. In some states the grizzly is still hunted.

McCracken's book is recommended to all interested in the grizzly bears and the part they played in life on this continent.—*William P. Dasmann, California Department of Fish and Game.*

The Elements of Chromatography

By Trevor Illtyd Williams; Philosophical Library, Inc., New York, 1955; xii + 90 p., 36 figs. $3.75.

The simple but sensitive chemical analysis known as chromatography has been applied to the field of biological research. Workers in fishery investigation have explored its use, particularly in the problem of race determination. At present, no clear value has resulted, and it now appears races cannot be sorted by this particular method; however, the issue is by no means closed. The method is successfully used in food and farm products investigations and it is a proven tool for many aspects of research.

Biologists who desire an introduction to this system of analysis should read *The Elements of Chromatography*. From this book the worker can continue to the growing literature on the subject.

The book describes the elements of the method, just as the title implies. It gives an historical review and proceeds through the development of the system to its present state of refinement.—*Robert R. Bell, California Department of Fish and Game.*

Outdoor Hazards Real and Fancied

By Mary V. Hood; The Macmillan Company, New York, 1955; xiii + 242 p., sketches by Don Perceval. $3.95.

By explaining logically the false fears of the uninitiated this book presents a new approach to the science of camping. Though written primarily as a guide for youth leaders, camp counselors, and parents, anyone interested in the out-of-doors should find it easy, interesting reading.

This book evolved from a series of lectures prepared by Mrs. Hood while serving as a consultant at Yosemite National Park. To her own background, as a nature photographer and lecturer, she has added the knowledge of many authorities in the field of science.

The four main objectives set forth are: to remove false fears; to acquaint campers with nature's relatively few hazards—means of avoiding them, and first aid for those unfortunate enough to become victims; to instill some of the principles of conservation; and to aid instructors to appreciate the privilege of introducing beginners to the joy of being outside (a somewhat intangible objective).

These are gained through systematic discussion of each animal and plant group containing any real or false hazard. Even the physical hazards which might be encountered by the camper have not been overlooked, as everything from electrical storms to blistered feet is discussed with the same general thoroughness as are plants and animals. The information is not limited to use in California and is of equal value to persons in all parts of the country.

The author has presented a great deal of material without excessive detail. For those interested in more detailed information an excellent set of references appears under general groupings in the appendix.

Probably the only compilation of material of this nature, "Outdoor Hazards" will most certainly win many a new friend for the out-of-doors and serve as a valuable reference for the seasoned camper.—*William L. Craig, California Department of Fish and Game.*

The Outdoorsman's Cookbook (Revised Edition)

By Arthur H. Carhart; The Macmillan Company, New York, 1955; 211 p., illus. $2.95.

Soothing aid to the dyspeptic hunter and camper, afflicted by the "sowbelly, beans, and bicarbonate" school, is extended by this guide to camp cookery. For "rawhide" pack trips or for base camp operations, this cookbook outlines simple, adequate meal planning. This new revised edition incorporates recent developments in dehydrated foods and the uses of aluminum foil.

Chapter II, "Mapping Your Meals", contains basic ration lists and packaging tips. Chapter III, "Your Fire", with 10 line drawings, illustrates campfires from the pole and billy-can type to stone and log barbecues and ovens.

The care of wild meat and fish is discussed and several wild game recipes are offered, including preparation of such intriguing gastronomics as muskrat, puma, opossum, and armadillo.

The bulk of the book is dedicated to basic "man-stuffing" camp recipes: soups, stews, meats, gravies, desserts, and breads, including an adequate account of the preparation of sour-dough.

This book is not a bride's primer, however. It assumes that the camp cook who tackles the recipes herein knows the rudiments of food preparation. And—why did Mr. Carhart overlook the greatest boon to camping since the friction match—the four-quart aluminum pressure cooker?—*Philip H. Arend, California Department of Fish and Game.*

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STATE OF CALIFORNIA

FISH AND GAME COMMISSION

Notice is hereby given that the Fish and Game Commission will meet on April 6, 1956, in Room W1098, State Employment Building, Seventh and Capitol Avenue, Sacramento, California, to receive recommendations from its own officers and employees, from public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds and mammals, or any species or variety thereof, in accordance with Section 16 of the Fish and Game Code.

Notice is hereby given, in accordance with Section 14.2 of the Fish and Game Code, that the Fish and Game Commission shall meet on May 25, 1956, in the California State Building, Los Angeles, to hear and consider any objections to its determinations and proposed orders in relation to birds and mammals for the 1956 hunting season, such determinations and orders resulting from hearing held on April 6, 1956.

FISH AND GAME COMMISSION
WM. J. HARP
Assistant to the Commission